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AEROJET
GENERAL TIRE
GENERAL

MASTER

REPORT NO 2510
TO
AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

RADIATION EFFECTS TESTING

CONTRACT SNP-1 MAY 1963 PROJECT NERVA

ROCKET ENGINE OPERATIONS—NUCLEAR

VOLUME V SECTIONS 31/W000-35/W000

RESTRICTED DATA—ATOMIC ENERGY ACT 1954

GROUP 1

Excluded from Automatic Regrading
DOD Directive 5200.10 Does Not Apply

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BY: TED REDMON DATE: 9-24-75

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COMPENDIUM OF RADIATION EFFECTS TEST PLANS SPECIFICATIONS AND REPORTS

TABLE OF CONTENTS

Volume	Series	Test No.	Item Description	Test Plans	Test Specs	Test Reports Prelim.
I	1	1/L001	TSOV Configuration No. 1	x	x	
	3	3/L001	TPA Bearing Sets	x	x	
		3/L002		x		
		3/L003		x		
	4	4/L001	TPCV Configuration No. 1	x	x	
	5	5/A001	TPCV Actuator	x		
	8	8/L001	Static Flanges and Seals	x	x	
		8/W001		x		
	14	14/W001	Control Drum Actuator Components	x	x	
		14/W002		x		
	15	15/W201	Reactor Tie Rod	x		
II	21	21/W001	Neutron Detectors	x	x	x
		21/W002		x	x	
		21/W003		x	x	
		21/W004		x		
		21/W005		x		
	22	22/W001	Neutron Detector Preamps & Cables		x	
		22/W002		x	x	
		22/W003		x	x	x
		22/W004		x	x	x
		22/W005		x	x	x
		22/W006		x	x	
		22/W007		x	x	
		22/W008		x		
		22/W009		x		
	23	23/A402	Strain Gages	x	x	
		23/L001	Accelerometers	x		
		23/L101	Resistance Temp. Transducers	x		
		23/L201	LVDT's	x		
		23/L301	Thermocouples	x		
		23/L302		x		
		23/L501	Pressure Transducers	x		
III		23/W002	Accelerometers	x	x	
		23/W004		x	x	
		23/W101	Resistance Temp. Transducers		x	
		23/W102		x	x	
		23/W104		x	x	
		23/W201	LVDT's	x		
		23/W203		x	x	
		23/W302	Thermocouples	x	x	
		23/W401	Strain Gages	x	x	

TABLE OF CONTENTS (cont.)

FOREWORD

The following system has been utilized in assigning numbers to the Radiation Effects Tests.

XX X XXX

Test number (see attached)

Test sponsor (A = AGC, Azusa Plant; L = LRP; W = WANL)

Test plan number (see attached list)

NOTES:

1. Tests are numbered sequentially.

2. Each test sponsor numbers his test independently and sequentially.

Test Plan No.	Basic Category	Test Number Breakdown	
1	TSOV Config. No. 1	001 -	
2	TSOV Config. No. 2	001 -	
3	TPA Bearing Sets	001 -	
4	TPCV Config. No. 1	001 -	
5	TPCV Actuator	001 -	
6	TPCV Config. No. 2	001 -	
7	Remote Disconnects	001 -	
8	Static Flange & Seals	001 -	099
9	--	001 -	
10	TVC Actuator	001 -	
11	Check Valve	001 -	
12	Gimbal Assembly	001 -	
13	Reactor Cooldown Valve	001 -	
14	Control Drum Actuators:		
	Actuator Drive Assembly	001 - 099	
	Actuator Servo Assy. (G.E. or Bendix)	101 - 199	
	Actuator Drive & Stop Assy. (G.E.)	201 - 299	
	Actuator Feedback Assy. (G.E.)	301 - 399	
	Actuator Aux. Comps. (Bendix)	401 - 499	
	Actuator Aux. Comps. (G.E.)	501 - 599	
	Actuator Housing Assy. (G.E. or Bendix)	601 - 699	
	Actuator Complete (G.E. or Bendix)	701 - 799	
	Act. Stepping Motor & Servo Assy.	801 - 899	
	Act. Mag. Particle Clutch	901 - 999	

15	Reactor Components:	
	Control Drum	001 - 099
	Lateral Support Assy.	101 - 199
	Tie Rod	201 - 299
	Spring & Support Sections	301 - 399
	--	401 - 499
	--	501 - 599
	--	601 - 699
	--	701 - 799
	--	801 - 899
	--	901 - 999
16	Propellant Feed System	001 - 099
17	Engine Control System	001 - 099
18	Pneumatic Power Supply	001 - 099
19	Pressurization System	001 - 099
20	--	001 - 099
21	Neutron Detectors	001 - 099
22	Neutron Detectors Preamps & Cables	001 - 099
23	Diagnostic Transducers:	
	Accelerometers	001 - 099
	Resistance Thermometers	101 - 199
	Displacement (position)	201 - 299
	Thermocouples	301 - 399
	Strain Gages	401 - 499
	Pressure Transducers	501 - 599
	--	601 - 699
	--	701 - 799
	--	801 - 899
	Microphones	901 - 999
24	Temperature Sensor (TCA)	001 - 099
25	Pressure Sensor (TCA)	001 - 099
26	Harness & Connectors	001 - 099
27	Amplifiers & Power Supplies	001 - 099
28	--	001 - 099
29	--	001 - 099
30	Reactor Logic System	001 - 099
31	Electronic Components	001 - 099
32	Electronic Circuits	001 - 099
33	Linear Potentiometers & Solenoids	001 - 099
34	Rotary Potentiometer & Solenoid	001 - 099
35	--	001 - 099
36	Shield Materials:	
	Basic Materials	001 - 099
	Capsules	101 - 199
	--	201 - 299
	--	301 - 399

INTRODUCTION

This document is a compendium of the NERVA program Radiation Effects Test Plans, Test Specifications and Preliminary Test Reports. A loose-leaf format has been established so that additions may be easily made as the program progresses.

The schedule for submission of these documents is as follows:

Preliminary Test Plans - To be submitted to SNPO by REON as a part of the yearly program plan.

Final Test Plans - To be submitted to SNPO by REON 2 months prior to the scheduled reactor test date.

Preliminary Test Specifications - To be submitted to the test reactor facility by REON 2 months prior to the scheduled reactor test date.

Final Test Specifications - To be submitted to SNPO and the test reactor facility by REON 1 month prior to the scheduled reactor test date.

Preliminary Test Reports - To be submitted to SNPO by REON 5 weeks after the scheduled reactor test.

FINAL TEST SPECIFICATIONS

I. EXPERIMENT IDENTIFICATION

A. Test Plan Reference No. — 31/W001 (insulated wires and coaxial cables)

B. Sponsor — WANL

C. Test Facility — WNY

D. Test Date — June 25 - 28, 1962

II. PURPOSE OF THE EXPERIMENT

A. To locate products which do not exhibit any appreciable transient or permanent radiation effects in the WNY reactor environment so that these items can be used on subsequent WNY tests without introducing unknown variables.

B. Materials and constructions will be tested so as to establish which of these offer the greatest promise of operating satisfactorily in a NERVA environment.

III. DRAWINGS

Not available at this time.

IV. EQUIPMENT LIST

A. To be provided by WANL

1. General Radio Electrometer, Type 1230A
2. Esterline-Angus Recorder, Type AW
3. 0-550 volt battery
4. Square Wave Generator, Tektronix No. 105
5. Wide Bank Preamplifier, Tektronix No. 1121
6. High Frequency Response Oscilloscope, Tektronix No. 543A
7. Polaroid Camera

B. To be provided by Test Facility

No special equipment required.

V. TEST ENVIRONMENT

A.	Temperature	ambient to 250°F
B.	Pressure	15 psig
C.	Humidity	very low
D.	Vibration	none
E.	Fast Neutron Flux (>1 Mev)	4×10^{12} n/cm^2/sec
F.	Thermal Neutron Flux	3×10^{13} n/cm^2/sec
G.	Gamma Flux	8×10^{7} R/hr (4×10^{13} Mev/cm^2/sec)
H.	Integrated Fluxes	
	Neutron (Fast) (>1 Mev)	2×10^{17} n/cm^2
	Neutron (Thermal)	
	Gamma	
I.	Fluid Environment	dry helium
J.	Duration	15 hrs

VI. ANALYTICAL

A.	Predicted Perturbed Fluxes	
B.	Radiation Heating	low, convection cooling should be adequate
C.	Activation Levels	

VII. FACILITY REQUIREMENTS

A.	Electrical	115 V, 60 cycles
B.	Pneumatic	none
C.	Hydraulic	none
D.	Special Fluids	dry helium
E.	Special Shielding	none

VIII. DOSIMETRY

A. Requirements

(These are not special and are to be used for all WNY tests.)

1. Thermal Flux - Bare and cadmium covered gold
   Bare and cadmium covered cobalt

2. Fast Flux - Nickel (5.0 Mev)
   Sulfur (2.9 Mev)
   Aluminum (8.1 Mev)

3. Gamma - Graphite-electrode ionization chamber (for dose rate magnitude and vertical distribution)
   Nitrous oxide capsules

IX. DATA HANDLING REQUIREMENTS

The data will be recorded manually, with the Esterline-Angus Recorder, and with the Polaroid Camera, and will be reduced manually.

X. TEST PROCEDURE

A. Receiving Inspection Procedure

Visual inspection for gross shipping damage

B. Pre-Irradiation Checkout

Insulated wires will be checked to determine the resistance of the insulation. Coaxial cables will also be checked for insulation resistance.

C. Reactor Installation Procedures

The experiments are to be placed in a 3" x 3" x 30" capsule.

The capsule will be purged and then pressurized to 15 psig with dry helium.

The bottom of the capsule will mate with the reactor core grid plate when the capsule is lowered into the WNY hole No. A3.

D. Pre-Irradiation Test Procedure
(Test items in irradiation position)

Insulated Wires: The insulated wires are wound around aluminum mandrels which serve as grounds for insulation resistance measurements. A battery will be used to apply from 300 to 500 volts between the wire and ground. The General Radio Electrometer will be used to measure the currents and the Esterline-Angus Instrument to record the results.

Coaxial Cables: The insulation resistance of the coaxial cable will be measured in the same manner except that the outer shields will be used as grounds rather than the mandrels. The coaxial cables will also be analyzed for their ability to transmit pulses. The square wave generator will apply pulses to one end of the cable and the wide band preamplifier and oscilloscope on the other end will display the pulses. A Polaroid camera will record the results. (WANL-TME-066 describes the Test Procedures in detail.)

E. Post-Irradiation Test Procedure

Data will be taken during and after irradiation in the same manner as in the pre-irradiation test procedure.

The capsule will be remotely disassembled and visually examined through appropriate shielding.

XI. HAZARDS

A. Personnel - No irregular hazards

B. Facility - No irregular hazards

XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES

Manual reduction, no special techniques.

XIII. DISPOSITION OF HARDWARE - Return equipment to WANL

XIV. SHIPPING AND RECEIVING INSTRUCTIONS - No Special instructions.

XV. APPENDIX - None

FINAL TEST SPECIFICATION

I. EXPERIMENT IDENTIFICATIONS

A.	Test Plan Reference No.	31/W002 (Resistors)
B.	Sponsor	WANL
C.	Test Facility	WNY
D.	Test Date	July 30 - Aug. 4, 1962

II. PURPOSE OF THE EXPERIMENT

The purpose of this test is to measure the performance characteristics of a variety of resistor types presently being considered for incorporation into both the pulse and DC preamplifier designs. This information is essential in the analysis of the NERVA preamplifier tests which will be performed in the WNY Reactor. Some resistors will also be coated with various insulating materials and analyzed for anticipated reduction in gas ionization effects.

III. DRAWINGS

Figure in WANL-TME-090 under Experiment No. 2

IV. EQUIPMENT LIST

A. To be provided by WANL

RCA Senior Volt-Ohmyst, Model WV-98C
Hewlett-Packard Model 412A, Vacuum Tube Voltmeter
General Radio Electrometer, Type 1230-A

V. TEST ENVIRONMENT

A.	Temperature	Ambient to 250°F
B.	Pressure	15 psig
C.	Humidity	very low
D.	Vibration	none
E.	Fast Neutron Flux (> 1 Mev)	4×10^{12} n/cm^2/sec

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F.	Thermal Neutron Flux	3×10^{13} n/cm^2/sec
G.	Gamma Flux	4.8×10^{13} mev/cm^2/sec
H.	Integrated Fluxes	
	Neutron (Fast) ($>$ 1 Mev)	2×10^{17} n/cm^2
	Neutron (Thermal)	1.6×10^{18} n/cm^2
	Gamma	2.6×10^{18} mev/cm^2
I.	Fluid Environment	dry helium
J.	Duration	15 hrs

VI. ANALYTICAL

A.	Predicted Perturbed Fluxes	
B.	Radiation Heating	low, convection cooling should be adequate
C.	Activation Levels	not appreciable

VII. FACILITY REQUIREMENTS

A.	Electrical	115 V, 60 cycles
B.	Pneumatic	none
C.	Hydraulic	none
D.	Special Fluids	dry helium
E.	Special Shielding	none

VIII. DOSIMETRY

A. Special Requirements - No special requirements

Same as 31/W001

IX. DATA HANDLING REQUIREMENTS

Because of the relatively low number of measurements to be taken, the data will be recorded and reduced manually.

X. TEST PROCEDURE (Reference WANL-TME-090 for detailed Test Procedure)

A. Receiving Inspection Procedure

Visual inspection for gross shipping damage.

B. Pre-Irradiation Checkout

The capsule assembly will be bench checked for insulation resistance of the resistors and their interconnecting wiring with the General Radio Electrometer.

C. Reactor Installation Procedures

The 3" x 3" by 30" capsule will be evacuated and then pressurized to 15 psig with dry helium. The capsule will be placed in WNY hole No. A3 and lowered until it engages the reactor core grid plate.

D. Pre-Irradiation Test Procedure
(Test items in irradiation position)

Most of the resistors will be run at rated wattage or as close to rated wattage as the power supply will allow. The wattage will be controlled by varying the power supply and a series rheostat. The resistance of the test specimens will be calculated from the current readings of the Hewlett-Packard 412A and voltage readings of the RCA Senior Volt-Ohmyst.

The resistance of the four 16K IRC MEF resistors will be measured at 0, 1/4, 1/2, and 1 watt.

The insulation resistances will be measured via the General Radio Electrometer.

E. Post-Irradiation Test Procedure

Data will be taken during and after irradiation in the same manner as in the pre-irradiation Test Procedure.

The capsule will be remotely disassembled and visually examined through appropriate shielding.

XI. HAZARDS

A. Personnel - No irregular hazards.

B. Facility - No irregular hazards.

XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES

Manual reduction, no special techniques.

XIII. DISPOSITION OF HARDWARE - Return equipment to WANL.

XIV. SHIPPING AND RECEIVING INSTRUCTIONS - No special instructions

XV. APPENDIX - None

NERVA PROGRAM

RADIATION EFFECTS TESTING

FINAL TEST SPECIFICATION

I. EXPERIMENT IDENTIFICATIONS

A.	Test Plan Reference No.	31/W003 (capacitors)
B.	Sponsor	WANL
C.	Test Facility	WNY
D.	Test Date	July 30 - Aug. 4, 1962

II. PURPOSE OF THE EXPERIMENT

This test is to measure the performance characteristics of a variety of capacitor types presently being considered for incorporation into both the pulse and DC preamplifier designs. This information is essential to the analysis of the NERVA preamplifier tests which are to be performed in the WNY Reactor.

III. DRAWINGS

Figures in WANL-TME-090 under Experiment No. 3.

IV. EQUIPMENT LIST

A. To be provided by WANL

Bench assembled capacitance bridge:

2 precision resistors
2 precision decade resistance boxes
1 precision decade capacitance box
1 Tektronix oscilloscope

B. To be provided by Test Facility

No special equipment required.

V. TEST ENVIRONMENT

A.	Temperature	Ambient to 250°F
B.	Pressure	15 psig
C.	Humidity	very low
D.	Vibration	none
E.	Fast Neutron Flux (> 1 Mev)	4×10^{12} n/cm^2/sec

F.	Thermal Neutron Flux		3×10^{13} n/cm^2/sec
G.	Gamma Flux		4.8×10^{13} Mev/cm^2/sec
H.	Integrated Fluxes		
	Neutron (Fast)	(> 1 Mev)	2×10^{17} n/cm^2
	Neutron (Thermal)		1.6×10^{18} n/cm^2
	Gamma		2.6×10^{18} mev/cm^2
I.	Fluid Environment		dry helium
J.	Duration		15 hrs

VI. ANALYTICAL

A.	Predicted Perturbed Fluxes	
B.	Radiation Heating	low, convection cooling should be adequate
C.	Activation levels	not appreciable

VII. FACILITY REQUIREMENTS

A.	Electrical	115 volts, 60 cycles
B.	Pneumatic	none
C.	Hydraulic	none
D.	Special Fluids	dry helium
E.	Special Shielding	none

VIII. DOSIMETRY

A.	Special Requirements	No special requirements

IX. DATA HANDLING REQUIREMENTS

Because of the relatively low number of measurements to be taken, the data will be recorded and reduced menually.

X. TEST PROCEDURE (Reference WANL-TML-090 for Detailed Test Procedure)

A. Receiving Inspection Procedure

Visual inspection for gross shipping damage.

B. Pre-Irradiation Checkout

The capsule assembly will be bench checked for insulation resistance of the capacitors and their interconnecting wiring.

C. Reactor Installation Procedures

The 3" x 3" x 30" capsule will be evacuated and then pressurized with 15 psig dry helium. The capsule will be placed in WNY hole No. A3 and lowered until it engages the reactor core grid plate.

D. Pre-Irradiation Test Procedure
(Test items in irradiation position)

The capacitance values of the nominal 100 MMFD and 1000 MMFD capacitors are to be measured at 10 KC. The remainder are to be measured at 1 KC. The bridge is to be manually balanced and the values manually recorded (a dummy cable is to be used in an adjacent let for cable compensation).

The General Radio Electrometer is to be used to measure capacitor leakage resistance. A known voltage is to be applied and the current is measured after it stabilizes.

E. Post-Irradiation Test Procedure

Data will be taken during and after irradiation in the same manner as in the pre-irradiation test procedure.

The capsule will be remotely disassembled and visually examined through appropriate shielding.

XI. HAZARDS

A. Personnel - No irregular hazards.

B. Facility - No irregular hazards.

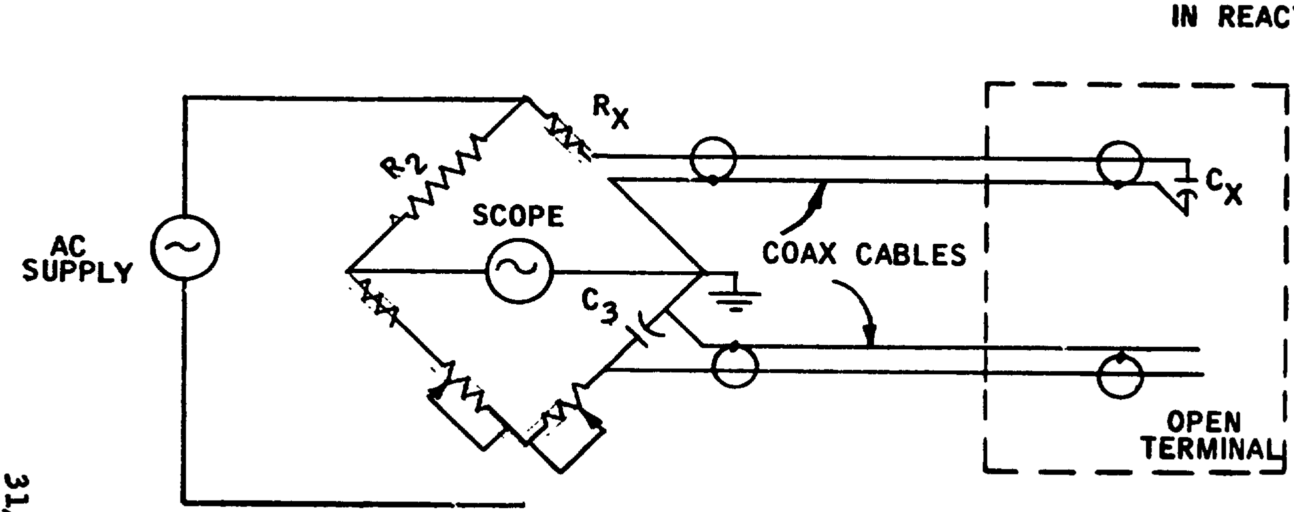
XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES

Manual reduction, no special techniques.

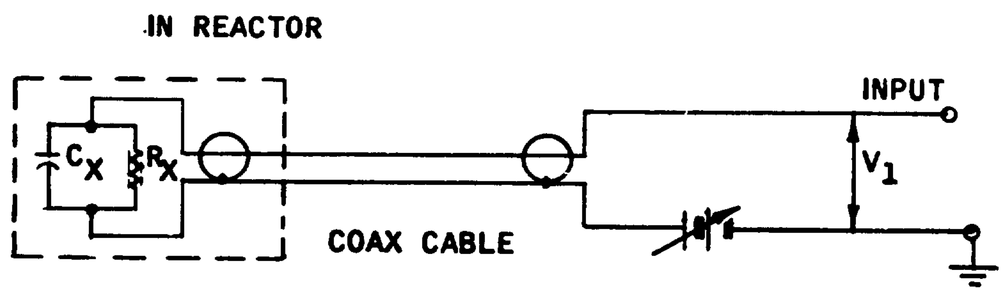
XIII. DISPOSITION OF HARDWARE - Return equipment to WANL

XIV. SHIPPING AND RECEIVING INSTRUCTIONS - No special instructions.

XV. APPENDIX - None



$$C_X = C_3 \frac{R_1}{R_2}$$



TO GENERAL RADIO ELECTROMETER
MODEL 1230-A

$$R_X = \frac{V}{V_1}\ RA - RA$$

FOR V_1 V

$$R_X = \frac{VRA}{V_1}$$

31/W003-1

NERVA PROGRAM

RADIATION EFFECTS TESTING

FINAL TEST PLAN

A.	Test Item Description	Electronics Components
B.	Test Date	November 1962 (WNY)
C.	Test Duration	6 hours
D.	Test Concepts	
	1. Static or dynamic	Dynamic
	2. Critical oper. parameters	DC leakage currents and high frequency of noise as a function of neutron and gamma exposure and tube characteristics
	3. Continuous or cyclic	Continuous
	4. Components included	1) Coaxial cables 2) Tubes 3) Electrically-insulating coatings
	5. Parameters to be measured	1) DC leakage current and high frequency noise 2) Grid, plate and filament currents and transconductance
	6. Use of data	To determine by analysis the ability of the components to meet the requirements for NERVA
	7. Pre- and Post-irradiation Examination	1) Coaxial cables a) Measure DC leakage currents at microvolt potential level on the center conductor b) Measure high frequency noise with a high DC voltage on the center conductor 2) Tubes (static measurements) a) Measure grid, plate and filament current and transconductance 3) Insulating coatings a) Measure leakage current at varied applied potential
E.	Environmental Conditions	
	1. Temperature	Below $125^{o}C$
	2. Neutron exposure	Fast = 1×10^{12} n/cm^2-sec (E > 2.9 Mev) Thermal = 7×10^{12} n/cm^2-sec integrated

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			Fast = 2.2×10^{16} n/cm^2
			Thermal = 1.5×10^{17} n/cm^2
	3.	Gamma exposure	3×10^{13} Mev/cm^2-sec 6.4×10^{17} Mev/cm^2
F.		Experimental Conditions	
	1.	Operation procedure	Apply operating voltages to the components and electrically measure parameters of interest.
	2.	Flow rates	Not applicable
	3.	Electrical Oper. condition	DC leakage measurements at microvolt potential and high frequency noise into high DC voltages. Tube voltage application and varying potential for insulating coatings
	4.	Internal pressures	Not applicable
G.		No. of tests planned	This test is only one planned for these components
H.		Number being tested	Cables (6) Tubes (9) Electrically insulating coatings (5)
I.		Basic description of component operation	Coaxial cables and vacuum tubes
J.		Manufacturer	Cables; Westinghouse, Raychem, Amphenol Tubes; RCA, Sylvania, Raytheon Coatings; G.E.; MMM
K.		Method of manufacture a) Materials b) Processes	Cables; magnesium oxide (RG-81) irradiated polyolefin (Raychem 32-195) and polyethylene drelectrics coatings glyptol, sythetimica lithafax, alumina
L.		Test designer	WANL

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RADIATION EFFECTS TESTING

FINAL TEST SPECIFICATION

I. EXPERIMENT IDENTIFICATION

A. TEST PLAN REFERENCE 31/W004, 31/W005, 31/W006 (Refer Below)

B. SPONSOR WANL

C. TEST DATE November 1962

D. TEST FACILITY WNY

II. PURPOSE OF THE EXPERIMENT

The purpose of these experiments is to perform initial screening of electronic components presently being considered for use in the NERVA reactor control system.

III. DRAWINGS

A. TEST ITEMS See Appendix

B. ELECTRICAL SINGLE LINE

1. Coaxial Cables 31/W004
   a. High Voltage Noise Measurement
   b. DC Leakage Current Measurement
   c. Linear Feedback Network
2. Electronic Tubes 31/W005
   a. Electronic Tube Arrangement
   b. Plug-in Adapter
   c. Block Diagram of Electronic Tube Test
3. Electrical Insulating Coatings 31/W006
   a. Location of Insulating Coatings
   b. Insulating Coating Test-Electrical Hookup

C. HYDRAULIC SINGLE LINE Not applicable

D. PNEUMATIC SINGLE LINE Not applicable

IV. EQUIPMENT LIST

A. TO BE PROVIDED BY NERVA

1. Test Items

a. Coaxial Cables (31/W004)

(1) Westinghouse WX 4403 Vacuum Cable

(2) Amphenol RG 149/U (polyethylene)

(3) Amphenol 21-541 (low-noise polyethylene)

(4) General Cable RG-81 (MgO)

(5) Raychem 32-195 (irrad. polyolefin)

b. Electronic Tubes (31/W005)

See table in appendix

c. Electrical Insulating Coatings (31/W006)

(1) Dow Corning 991 Varnish (50% solution of silicone resin in Xylene) - Unfilled

(2) Dow Corning 991 Varnish - Filled with No. 325 mesh synthamica No. 202 powder.

(3) GE RTV-60 Silcone Rubber Spray

(4) GC Electronics Red Glyptal Insulation Varnish (alkyd base)

(5) MMM "Scotchcast" No. 5 Epoxy Resin - Filled with alumina powder

(6) Krylon Acrylic Resin Spray

2. Data Acquisition System

B. TO BE PROVIDED BY TESTING AGENCY

1. Dosimetry

V. TEST ENVIRONMENT

A. TEMPERATURE

The interior of the test capsule will be filled with dry helium gas and maintained at a static pressure of 15 psig throughout the pre-irradiation, irradiation, and post-irradiation test phases. Free convection of the helium gas will provide sufficient cooling in order to maintain component temperatures below their maximum rated values (approximately 125°C).

B.	PRESSURE	15 psig
C.	HUMIDITY	Not applicable
D.	VIBRATION	Not applicable
E.	FAST NEUTRON FLUX	1.2×10^{12} nv (E > 2.9 Mev)
F.	THERMAL NEUTRON FLUX	4×10^{12} nv
G.	GAMMA-RAY FLUX	10^{8} R/hr
H.	INTEGRATED DOSE	
	1. Neutron-Fast	1.7×10^{16} nvt (E > 2.9 Mev)
	2. Thermal Neutron	5.8×10^{16} nvt
	3. Gamma	2×10^{8} R (4.3×10^{17} mev/cm^2)
I.	FLUID ENVIRONMENT	Static helium
J.	DURATION	

VI. ANALYTICAL

A.	PREDICTED PERTURBED FLUXES	Self-shielding of experiments because of size and material of minor nature.
B.	RADIATION HEATING	Not significant
C.	ACTIVATION LEVELS	Not significant

VII. FACILITY REQUIREMENTS

A.	ELECTRICAL	110 v, 60 cps
B.	PNEUMATIC	Not applicable
C.	HYDRAULIC	Not applicable
D.	SPECIAL FLUIDS	Not applicable
E.	SPECIAL SHIELDING	Not applicable

VIII. DOSIMETRY

A. SPECIAL REQUIREMENTS

Prior dosimetry information will be used. Measure the gamma intensity using a 4cc graphite-electrode ionization chamber.

IX. DATA HANDLING REQUIREMENTS

A. COAXIAL CABLES

To be supplied by WANL

B. ELECTRONIC TUBES

To be supplied by WANL

C. ELECTRICAL INSULATING COATINGS

X. TEST PROCEDURE (Ref. WANL-TME-169)

A. RECEIVING INSPECTION PROCEDURE

Equipment will be hand carried by WANL to WNY

B. PRE-IRRADIATION CHECKOUT (Lab area)

C. REACTOR INSTALLATION PROCEDURES

All of the experiments will be placed within the 3 x 3 x 30 in. aluminum capsules except for the coaxial cable, which will be placed within a 3 in. dia stand pipe. Experiment hole A3 will be used.

D. PRE-IRRADIATION TEST PROCEDURE

(Test items in irradiation position).

1. Coaxial Cables

Test for noise and leakage current

2. Electronic Tubes

Measure the following: "Short"; leakage; transconductance; plate current; grid current; filament current; life test: gas test.

Cable leakage currents will be measured with an electometer primarily to check for cable failures and to serve as a point of reference.

Photographs of oscilloscope traces will be used to record observed noise levels.

d. Reactor Power Schedule

Test the cables at zero power, 10 KW, 100 KW, and 1 MW with noise and leakage current measurements made at each level.

2. Electronic Tubes

Upon completion of the pre-irradiation tests, the capsule will be placed into the core of the reactor and the reactor brought up to full power. At full power (1 megawatt) the same tests will be made as were made during pre-irradiation tests.

3. Electrical Insulating Coatings

The insulation resistance will be measured at 300 v dc potential during pre-irradiation tests, at zero reactor power, 10 KW reactor power, 100 KW reactor power, 1 MW reactor power and post-irradiation. Except at the 1 MW reactor power level only one set of readings will be taken after which the reactor power will be increased to a higher level. After reactor power reaches the 1 MW level, readings will be taken at 1/2 hour intervals throughout the power run to measure the effect of integrated dosage.

F. POST-IRRADIATION TEST PROCEDURE

1. Coaxial Cables (31/W004)

Test for noise and leakage after the cables in the stand pipe have been removed to the storage rack.

2. Electronic Tubes (31/W005)

When the reactor is shut down, the capsule will again be placed into the storage rack and then permitted to cool to ambient temperature.

3. Electrical Insulating Coatings

Measure insulation resistance at a 300 v dc potential.

E. IRRADIATION TEST PROCEDURE

1. Coaxial Cables

a. Mechanical Arrangement

The cables to be tested will be installed in a standpipe for insertion in the reactor core. The cable ends will be sealed with potting compound before insertion in the standpipie and located in such a manner as to eliminate end effects.

b. Induced DC Leakage Currents

The test circuit will be used to measure d-c leakage currents at low applied potentials. The same cables as tested for noise will be tested for leakage current. The operational amplifier will serve as a high gain feedback type linear microammeter. Offset will be carefully adjusted to a minute value with the amplifier balance control. This will minimize amplifier input current requirements and reduce with potential on the cable under tests to virtually zero volts (20 to 100 microvolts).

The range of the linear microammeter is adjustable over a wide range as determined by the feedback network. For best accuracy and minimum offset the amplifier output voltage will be maintained at 1 v or less by selecting the proper range. Induced cable current will be determined by amplifier output voltage and the feedback resistor used $\left[I = (V\ out/R_F) \right]$.

c. High Voltage Noise Test

A potential of 900 v dc will be applied to the center conductor with both positive and negative polarities. Noise will be monitored (with and without terminating impedances on the cable input) with an oscilloscope and preamplifier.

A series of high pass filters will be used to ascertain the frequency characterisitcs of the noise.

When the temperature has stabilized, post-irradiation data will be taken. Again, the same tests as were made in pre-irradiation will be made in post-irradiation.

3. Electrical Insulating Coatings (31/W006)

Post-irradiation inspection for physical damage to the test coatings (after cooldown) will be performed for correlation with measured performance.

XI. HAZARDS

A. PERSONNEL None

B. FACILITY None

XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES TO BE USED

To be carried out by WANL

XIII. SHIPPING & RECEIVING INSTRUCTIONS

To be WANL responsibility.

XIV. APPENDIX

See following pages.

ELECTRONIC TUBES TO BE TESTED
31/W005

Tube Group	Manufacturer	Type Number	Tube Type	Characteristics	Size and Weight	Materials
1	Raytheon	CK5886	Subminiature Glass Bulb T - 2 x 3	Electrometer Pentode Fil = 1.25 v at 10 μa Max Plate Cur = 300 ma μ = 175; Gm = 175	H 1.5" x W .285" x L .4" 2.6 grams	Note A
2	Raytheon	CK5889	Subminiature Glass Bulb T3	Pentode Fil = 1.25 v at 7.5 ma Max Plate Cur = 300 ua μ = 250; Gm = 10	H 1.75" x dia .400" 2.65 grams	Note A
3	Sylvania	6112	Subminiature Glass Bulb T3	Dual Triode Fil = 6.3 v at 300 ma Max Plate Cur 3.3 ma μ = 60 to 80; Gm = 1800	H 1.75" x dia .40" 3.5 grams	Note A
5	RCA	7586/ A15212	Nuvistor Metal Shell	Triode Fil = 6.3 v at 140 ma Max Plate Cur = 20 ma μ = 35; GM = 10,000	H .8 x dia .5" 1.9 grams	
5	RCA	7587/ A2702	Nuvistor Metal Shell	Tetrode Fil = 6.3 v at 150 ma Max Plate Cur = 20 ma Gm = 10,000	H 1.05" x dia .5" 2.35 grams	
6	RCA	7895/ A15321	Nuvistor Metal Shell	Triode Fil = 6.3 v at 135 ma Max Plate Cur = 15 ma μ = 64; Gm = 9500	H .8" x dia .5" 1.9 grams	Note B
7	Sylvania	7963	Subminiature Glass Bulb T3	Dual Triode Fil = 6.3 v at 350 ma Max Plate Cur = 22 ma μ = 40; Gm = 13,000	H 1.375" x dia .400" 4.0 grams	

ELECTRONIC TUBES TO BE TESTED (cont.)

Tube Group	Manufacturer	Type Number	Tube Type	Characteristics	Size and Weight	Materials
8	RCA	8056/ A15319	Nuvistor Metal Shell	Triode Fil = 6.3 v at 135 ma Max Plate Cur = 15 ma μ = 12.5; Gm = 8000	H .8" x dia .440" 1.9 grams	Note B
9	Sylvania	8185	Subminiature Glass Bulb T3	Triode Fil = 6.3 v at 300 ma Max Plate Cur = 50 ma μ = 42; Gm = 19,000	H 1.625" x dia .400" 4.4 grams	

NOTE A: No actual material list was available but because of the similarity of the tubes it is believed that the materials are essentially the same as types 7963 and 8185.

NOTE B: No actual material list was available but because of the similarity of the tubes it is believed that the materials are essentially the same as types 7586 and 7587.

PARTS LIST FOR THE 7586 AND 7578*

Envelope	No. 52 Alloy (50% nickel, 50% iron)
Stem wafer	Forsterite ceramic
Anode	330 Grade Electronic Nickel
Element Support	Copper plated steel (SAE 1010)
Flanges	
Stem leads	Copper plated molybdenum
Grid	Copper plated molybdenum and nickel plated molybdenum
Cathode support sleeve	Nickel chromium alloy
Heater	Tungsten - alumina coating
Cathode	High purity nickel; barium-strontium-calcium carbonate coating
Seal Braze and metallizer	Molybdenum-Germanium-copper alloy

TOTAL MATERIAL BY WEIGHT

Material	Weight in grams x 10^{-3}
Aluminum oxide	3.5
Barium	0.22
Calcium	0.03
Chromium	0.8
Copper	59.8
Forsterite	338.5
No. 52 Alloy (50% ni, 50% iron) (plux 0.5% Mn, 0.3% Si, 0.15% Cu, 0.06% C, Trace of Cobalt)	1143.1
Germanium	6.54
Manganese	0.03
Molybdenum	131.5
Nickel	49.4
SAE 1010 Carbon Range: 0.05 - 0.15% Manganese: 0.30 - 0.60% Phosphorus (max): 0.045% Sulpher (max): 0.055%	90.0
Strontium	0.27
Tungsten	3.4

*The parts list for type 7587 is identical with the addition of a top cap of the same material as the envelope above and a ceramic spacer, of the same material as the stem wafer above.

MATERIALS LISTS FOR SYLVANIA FRAME GRID SUBMINIATURE TUBES 7963 AND 8185

Tube Part	Material	Tube Type
Heater wire	Tungsten coil	Both
Heater wire coating	Alundum	Both
Cathode sleeve	220 nickel	Both
Cathode tab	Dotab (nickel alloy)	Both
Cathode coating	Oxide coating of Ba O/Sr O/Ca O	Both
Mica spacers	Mica 0.006 to 0.011 in. coated with magnesium oxide	Both
Stem leads	0.017 in. Dumet wire tinned exterior to glass	Both
Stem glass	Corning Type 8161	Both
Bulb glass	Corning Type 0120	Both
Plate	Carbonized, nickel plated steel	Both
No. 1 grid side rods	Molybdenum	Both
No. 2 grid straps	Molybdenum	Both
No. 1 grid laterals	Tungsten wire	Both
Support rods	Nickel plated steel	7963
Heater connectors	Nickel plated steel	Both
No. 1 grid connector	Nickel	Both
Kemet Getter		7963
Rectrangular loop	Nickel	
Getter bar	Iron clad barium	
Getter material (flushed)	Barium, aluminum	
Stabil Getter		8185
Ring	Nickel or nickel plated steel	
Getter material (flushed)	Barium, aluminum, nickel	

NERVA PROGRAM

RADIATION EFFECTS TESTING

Section No: 1.5.2.8.0
System: Controls
Component:
Test: 31/W004, 31/W005, 31/W006
Date: June 1963

PRELIMINARY TEST REPORT

I. SUMMARY

Electronic components were irradiated in the WNY Reactor during the period 29 October through 2 November 1963. Total dosage can only be estimated since the ion chamber did not function. Estimates place the dosage rate at 5×10^7 R/hr. Temperatures in cables ran as high as 350°F at 1 MW reactor power which caused one cable to short out. Polarity of induced currents in the RG-149U cables reversed twice in a 10hour interval at 1 MW power.

The electronic tubes grid and plate currents were permanently affected by the radiation to the extent that pre-irradiation values were exceeded by as much as 75% in transconductance, 100% in plate current and 200% in grid current. The subminiature glass triode tubes exhibited the greater change and the nuvistors had the least change.

The insulating coatings proved to be of value in the radiation environment by a factor of 10 over uncoated insulators. While the insulation properties of the coatings were gradually reduced during full power, recovery after irradiation was excellent.

II. IDENTIFICATION

A.	TEST NO.	31/W004, 5, 6
B.	TEST DATE	29 October through 2 November 1962
C.	TEST SPONSOR	WANL
D.	TEST FACILITY	WNY

III. PURPOSE

To perform initial screening of electronic components presently being considered for use in the NERVA Reactor Control System.

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IV. TEST ITEM DESCRIPTION

A. COAXIAL CABLES (See Figures 1 through 3)

1. Westinghouse WX 4403 Vacuum Cable

2. Amphenol RG 149/U (Polyethelene)

3. Amphenal 21-541 (Low Noise Polyethelene)

4. General Cable RG-81 (MgO)

5. Raychem 32-195 (Irradiated Polyolefin)

B. ELECTRONIC TUBES (See Figures 4 through 6)

See Table I for Tube Identification. See Table II for Materials List.

C. ELECTRICAL INSULATING COATINGS (See Figures 7 and 8)

1. Dow-Corning Varnish No. 991 (50% solution of silicone resin in xylene) Unfilled

2. Dow-Corning Varnish No. 991 - Filled with No. 325 Mesh Synthamica No. 202 Powder

3. GE RTV - 60 Silicone Rubber Spray

4. G.C. Electronics Red Glyptal Insulation Varnish (Alkyd Base)

5. MMM "Scotchcast" No. 5 Epoxy Resin - Filled with Alumina Powder

6. Krylon Acrylic Resin Spray

V. RADIATION TEST DESCRIPTION

A. SAMPLE PREPARATION

1. Coaxial Cables

(a) The braided shield on the end of the cable to be placed in the reactor was stripped back about 1 in. and coated with silicone rubber (Dow-Corning Silastic RTV881). The end was then covered with a fiberglass tape (MMM). The cables, together with 2 copper-constantan thermocouples, were bundled together using fiberglass tape. The thermocouples were attached to the metal sheaths on the Westinghouse vacuum cable and the magnesium oxide cable (RG81).

(b) In order to determine whether "end" effects would be experienced during the tests, an additional sample of the Raychem 32-195 cable was included in the bundle and doubled back about 15 ft so that its end was out of the radiation field.

(c) The bundle of cables was placed in a 3 in. dia standpipe which was located in the core of the WNY reactor during the radiation tests.

2. Electronic Tubes

The tubes were placed in a 3 x 3 x 30 in. aluminum capsule.

3. Electrical Insulation Coatings

Specimens were placed in a 3 x 3 x 30 in. aluminum capsule.

B. REACTOR POWER PROGRAM

Based upon foils that were located in the interiors of the capsules irradiated during prior experiments, the following neutron fluxes are estimated for this test:

Fast Neutron ($E > 2.9$ Mev) = 1.2×10^{12} n/cm^2-sec
Thermal Neutron (Cd difference) = 3.9×10^{12} n/cm^2-sec

Attempts to measure the gamma dose rate with the 4-CC graphite Ion chamber were not successful due to the fact that the chamber was found to be damaged internally. It will be returned to General Dynamics/Fort Worth for the necessary repairs and it is hoped that it will be available for measurements during the test series planned in December. In the meantime, it is felt that a gamma dose rate of 5×10^7 R/hr is still the best available value.

VI. RESULTS

A. COAXIAL CABLES TESTS

1. Induced Current Measurements

Radiation-induced currents were measured at zero applied potential using a linear micro-microammeter.

Since only free convection of air was available for cooling the cables, the temperatures at 1 MW ran as high as 350°F. Although such temperatures far exceed the maximum value specified for polyethylene, useful data were gathered on all of the cables except that during the last 15 min of the test the 21-541 cable shorted out.

In general, the RG149/U cable appeared to be the most immune to radiation induced currents, showing currents ranging from $+7 \times 10^{-9}$ to -4×10^{-9} amp at the 1 MW radiation levels. Oddly enough, the induced current in the RG-149/U cable changed polarity twice during the 1-hour interval that the reactor was at 1 MW. The RG81/U and the vacuum cable showed the largest induced currents ranging approximately 10 times higher than the RG149/U.

In order to determine the effect of the high temperature on the induced currents measured, the RG149/U, 21-541, RG59/U and the Raychem 32-195 cables were tested in an oven up to the maximum temperatures reached during the reactor test. No induced currents were observed during any phase of the oven tests.

Upon completion of the oven test, an identical set of cables was vibrated on a shake table over a frequency range of 5 to 2000 cps with an acceleration range of 2 to 7 g. Using the same instrumentation setup as before, no induced currents could be found.

2. Noise Measurements

The testing of cables with high voltage applied (+900 v) for radiation induced noise did not disclose any alarming effects. The worst case observed was on the RG81 cable which indicated a generated noise level of approximately 85 microvolts. The other cables indicated a peak noise level in the order of 50 to 65 microvolts at the 1 MW reactor power level. These measurements were made with a peak noise of 40 microvolts in the measuring system. Noise measurements were made with a 100 KC high pass filter. Measurements with 500 KC and 1 MC filters indicated negligible changes in noise level indicating noise to be predominantly higher frequencies.

The noise levels were essentially the same at all lower power levels and indicated about a 50 microvolt peak noise level.

B. ELECTRONIC TUBE TEST

In general, there were no complete failures due to irradiation of the tubes. An important factor here may have been the ambient gas and tube temperatures which were kept to a minimum. The highest temperature recorded (168°F) was on a nuvistor tube at 1 megawatt. The subminiature glass triode tubes exhibited the greatest changes with permanent increases in plate current, grid current and transconductance. The largest change was in one section of a 6112 where the post-irradiation values differed from the pre-irradiation values by the following amounts: 75% increase in transconductance, 100% increase in plate current, and a 200% increase in grid current (largest grid current was 2.15 μa). The other subminiature glass triodes exhibited similar increases in plate current, grid current and transconductance but were smaller in magnitude than the example given above.

The nuvistors exhibited smaller changes in their characteristics, with approximately 30% increase in plate current and transconductance, and about 10% increase in grid current for the worst cases. One nuvistor did, however, exceed the average changes exhibited by the other nuvistors. This tube indicated a slight gassy effect in tests performed at 1 megawatt. This effect was not evident in the post-irradiation test. However, the transconductance reading at this point was drifting.

The subminiature glass electrometer tubes had grid currents in the order of 5 x 10^{-9} amp at a 1 megawatt while the plate currents exhibited a slight decrease.

Nearly all of the tubes exhibited a small increase in filement current. However, there was only 3.3% increase in the worst case.

C. ELECTRICAL INSULATING COATINGS TEST

The insulating coatings test proved the value of circuit coating; however, the results were not up to expectations. The best insulation recorded at the end of 4 hours was 95 megohms to ground on an insulator coated with mica filled silicone resin. Another insulator coated with the same material indicated a resistance to ground of 11.4 megohms at the same time. This was only a factor of 10 better than the uncoated insulators. The glyptal, unfilled silicone resin and the filled epoxy resin insulations were about 5 to 15 megohms at the end of the test with the filled epoxy appearing the best of the three.

The insulation of the samples generally decreased during the full power run from 25 to 50%. All exhibited excellent recovery after irradiation.

It was noted during the full power run that reversing the applied potential from a positive to a negative voltage reduced the leakage currents considerably. A factor of 100 improvement in the apparent insulation resistance was observed.

VII. CONCLUSIONS

Conclusions regarding the suitability of the components tested during these experiments for use in the NERVA environments will be prepared after a more detailed analysis of the data has been completed. This detailed information including plots of component performance, dosimetry, etc., will be published as a technical memorandum within 1 or 2 months.

TABLE I

ELECTRONIC TUBES TESTED

Tube Group	Manufacturer	Type Number	Tube Type	Characteristics	Size and Weight	Materials
1	Raytheon	CK5886	Subminiature Glass Bulb T - 2 x 3	Electrometer, Pentode Fil = 1.25 V at 7.5 ma Max Plate Cur = 300 ma μ = 175; Gm = 175	H 1.5" x W .285" x L .4" 2.6 grams	Note A
2	Raytheon	CK5889	Subminiature Glass Bulb T3	Pentode Fil = 1.25 v at 7.5 ma Max Plate Cur = 300 ma μ = 250; Gm = 10	H 1.75" x dia .400" 2.65 grams	Note A
3	Sylvania	6112	Subminiature Glass Bulb T3	Dual Triode Fil = 6.3 v at 300 ma Max Plate Cur = 3.3 ma μ = 60 to 80; Gm = 1800	H 1.5" x dia .40" 3.5 grams	Note A
4	RCA	7286/ A15212	Nuvistor Metal Shell	Triode Fil = 6.3 v at 140 ma Max Plate Cur = 20 ma μ = 35; Gm = 10,000	H .8 x dia .5" 1.9 grams	
5	RCA	7587/ A2702	Nuvistor Metal Shell	Tetrode Fil = 6.3 v at 150 ma Max Plate Cur = 20 ma Gm = 10,000	H 1.05" x dia .5" 2.35 grams	
6	RCA	7895/ A15321	Nuvistor Metal Shell	Triode Fil = 6.3 v at 135 ma Max Plate Cur = 15 ma μ = 64; Gm = 9500	H .8" x dia .5" 1.9 grams	Note B
7	Sylvania	7963	Subminiature Glass Bulb T3	Dual Triode Fil = 6.3 v at 350 ma Max Plate Cur = 22 ma μ = 40; Gm = 13,000	H 1.375" x dia .400 4.0 grams	

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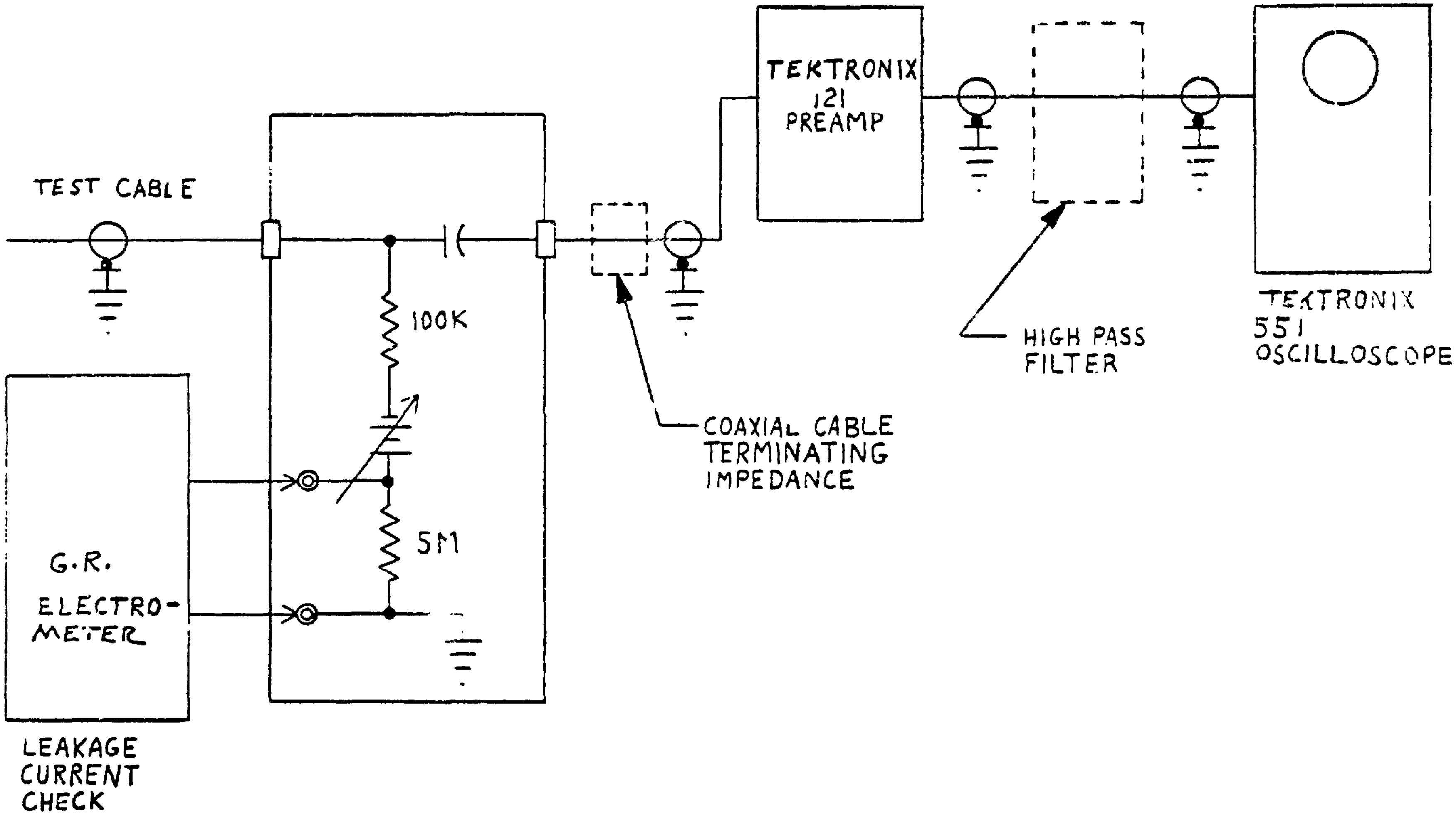
TABLE I (cont.)

Tube Group	Manufacturer	Type Number	Tube Type	Charcteristics	Size and Weight	Materials
8	RCA	8056/ A15319	Nuvistor Metal Shell	Triode Fil = 6.3 v at 135 ma Max Plate Cur = 15 ma μ = 12.5; Gm = 8000	H x dia .8" x .440" 1.9 grams	Note B
9	Sylvania	8185	Subminiature Glass Bulb T3	Triode Fil = 6.3 v at 300 ma Max Plate Cur = 50 ma μ = 42; Gm = 19,000	H x dia 1.625" x .400" 4.4 grams	

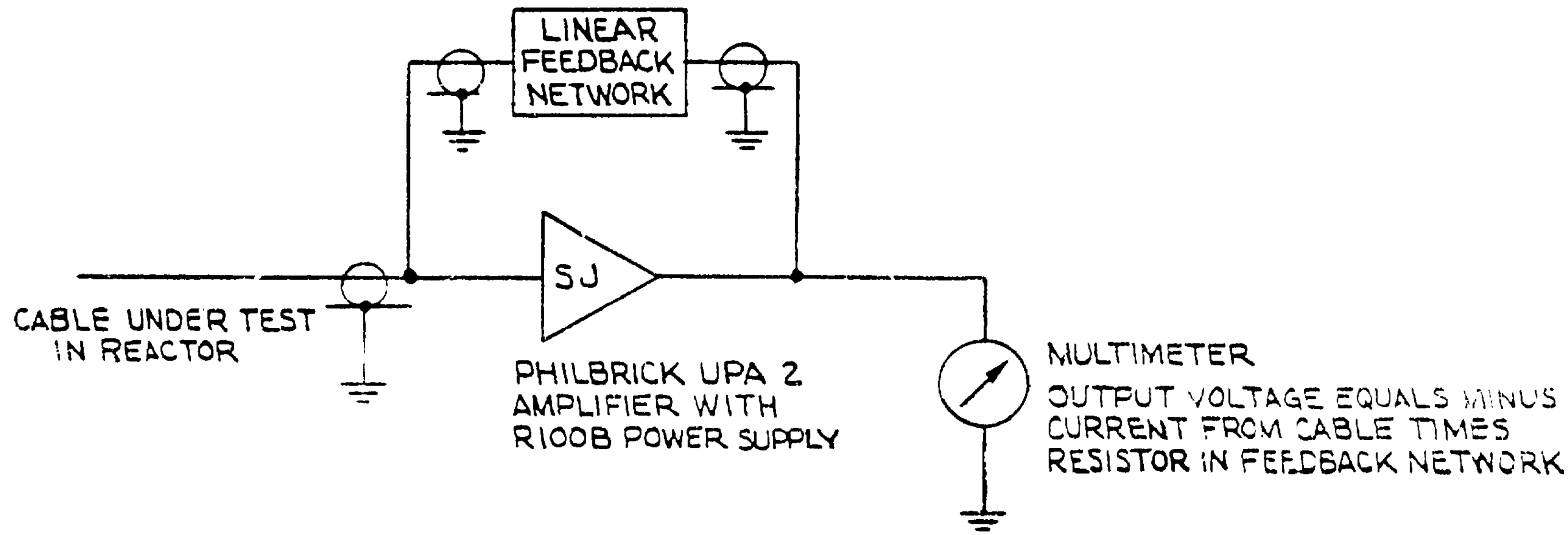
NOTE A: No actual material list was available but because of the similarity of the tubes it is believed that the materials are essentially the same as types 7963 and 8185.

NOTE B: No actual material list was available but because of the similarity of the tubes it is believed that the materials are essentially the same as types 7586 and 7587.



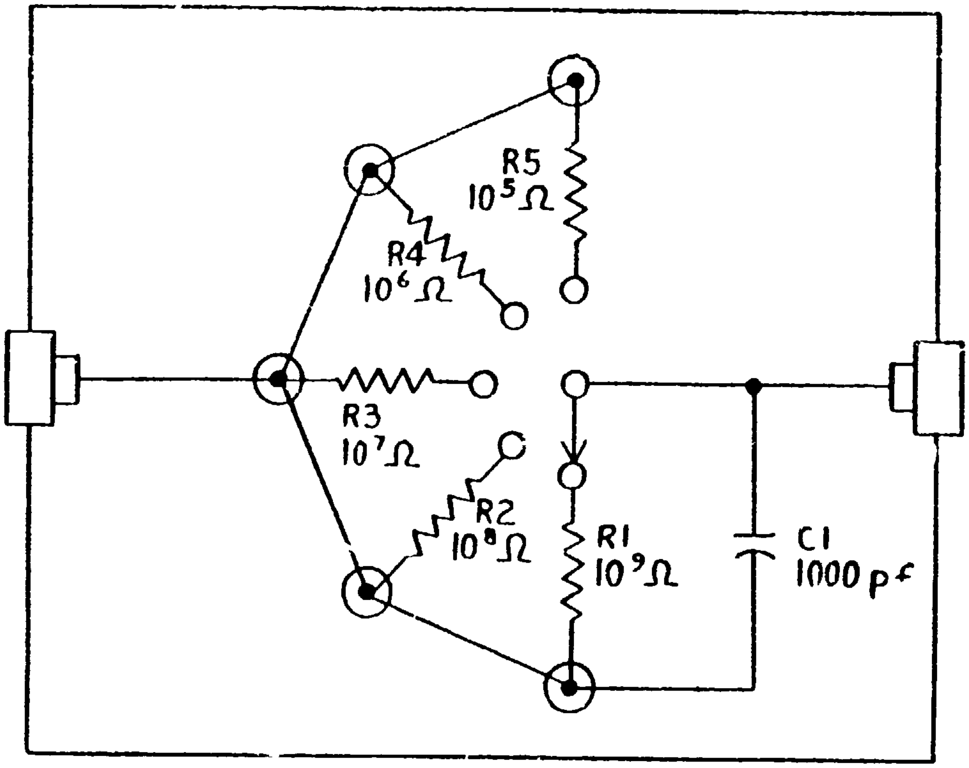
HIGH VOLTAGE NOISE MEASUREMENT

31/W004,5,6-1



DC LEAKAGE CURRENT MEASUREMENT

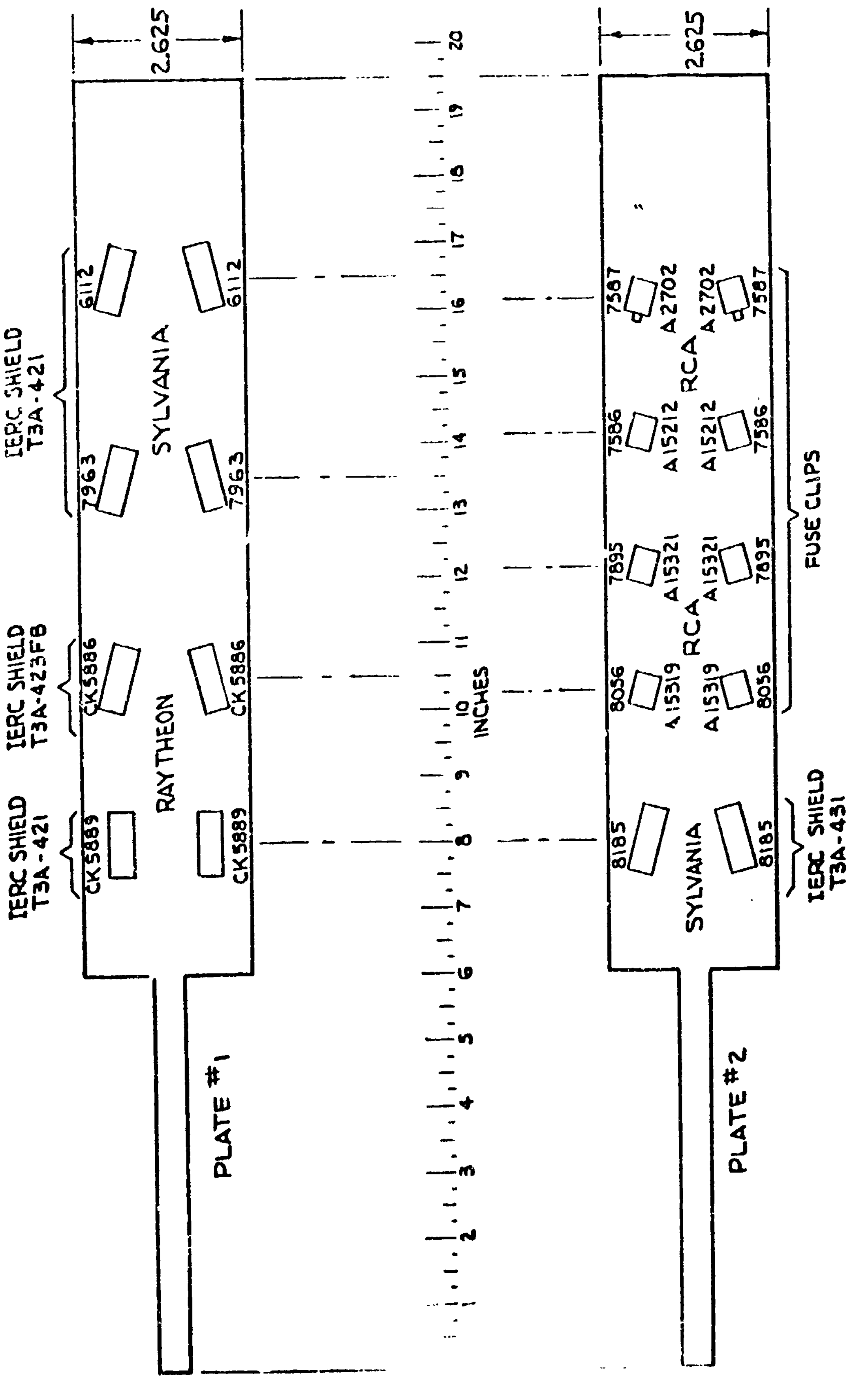
31/W004,5,6-2



ALL RESISTORS ± 5%

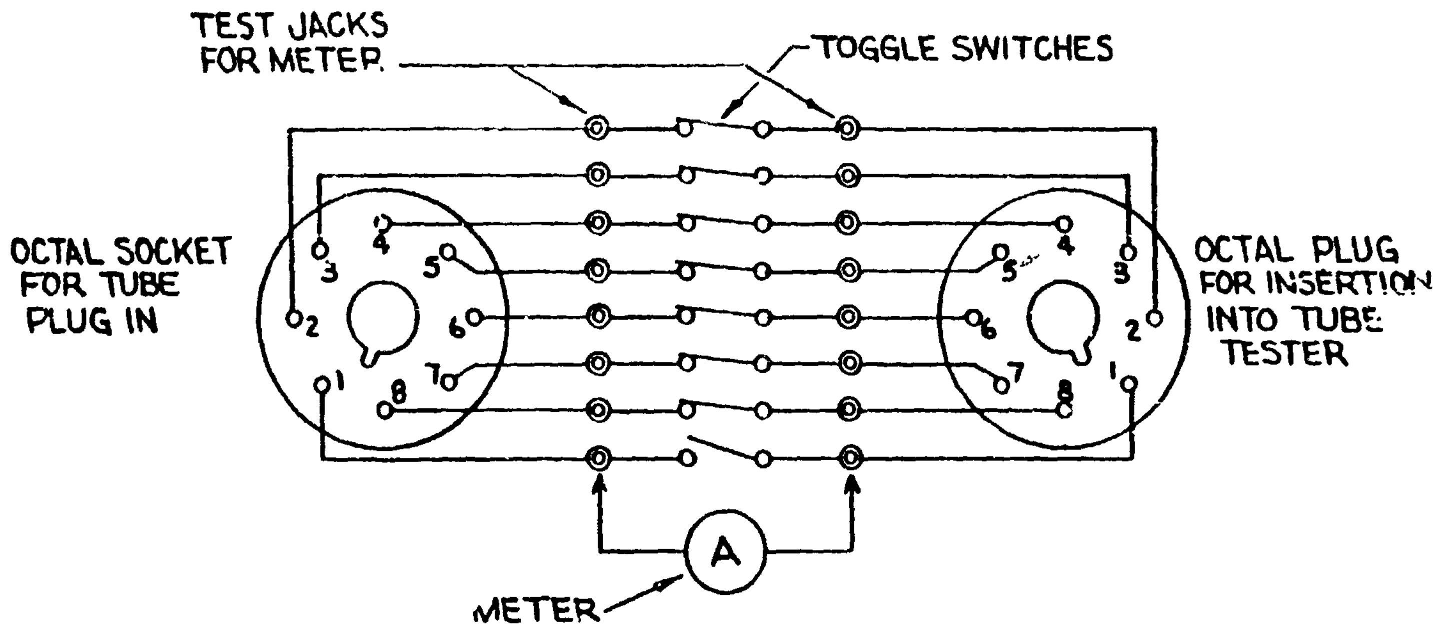
LINEAR FEEDBACK NETWORK

31/W004,5,6-3



ELECTRONIC TUBE ARRANGEMENT

31/W004,5,6-4


TEST JACKS
FOR METER
TOGGLE SWITCHES
OCTAL SOCKET
FOR TUBE
PLUG IN
OCTAL PLUG
FOR INSERTION
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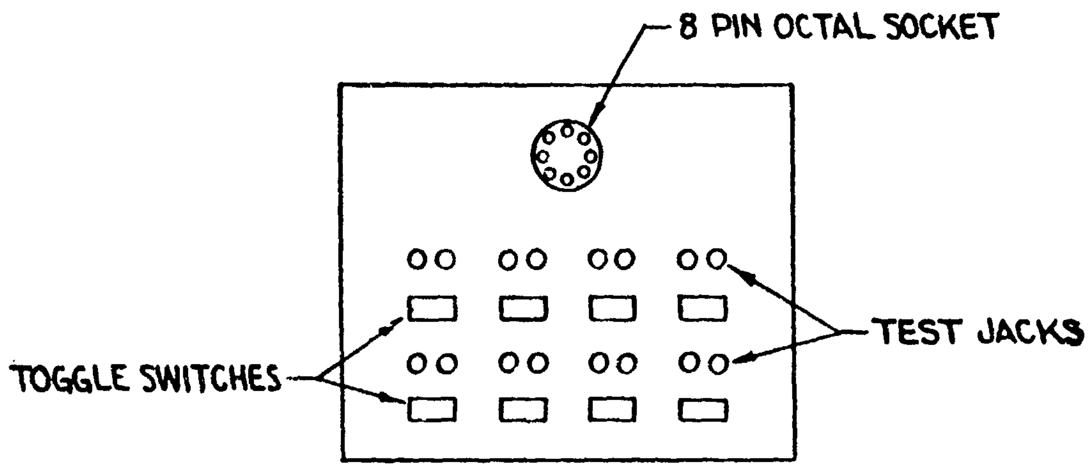
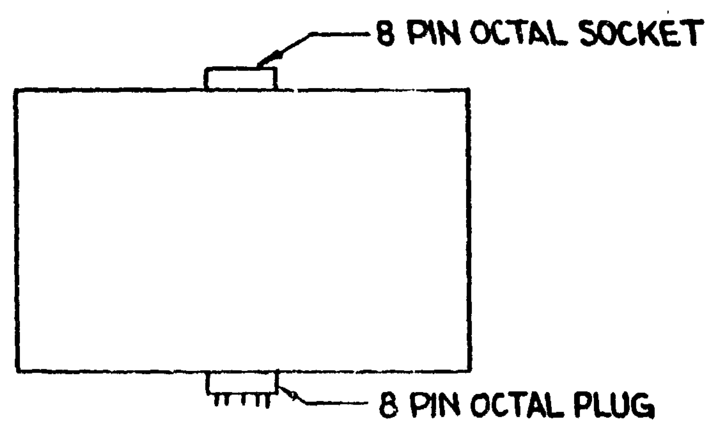
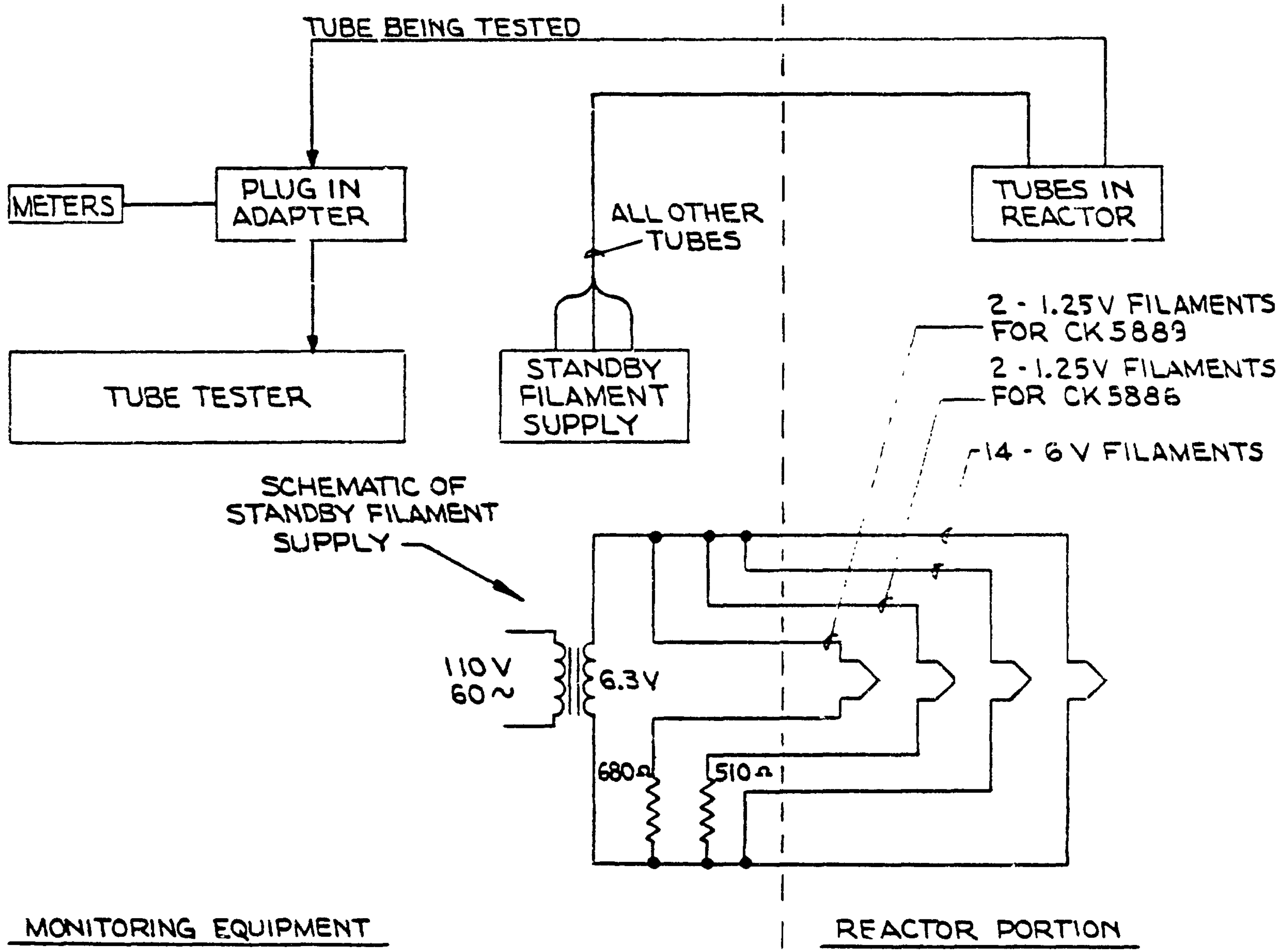
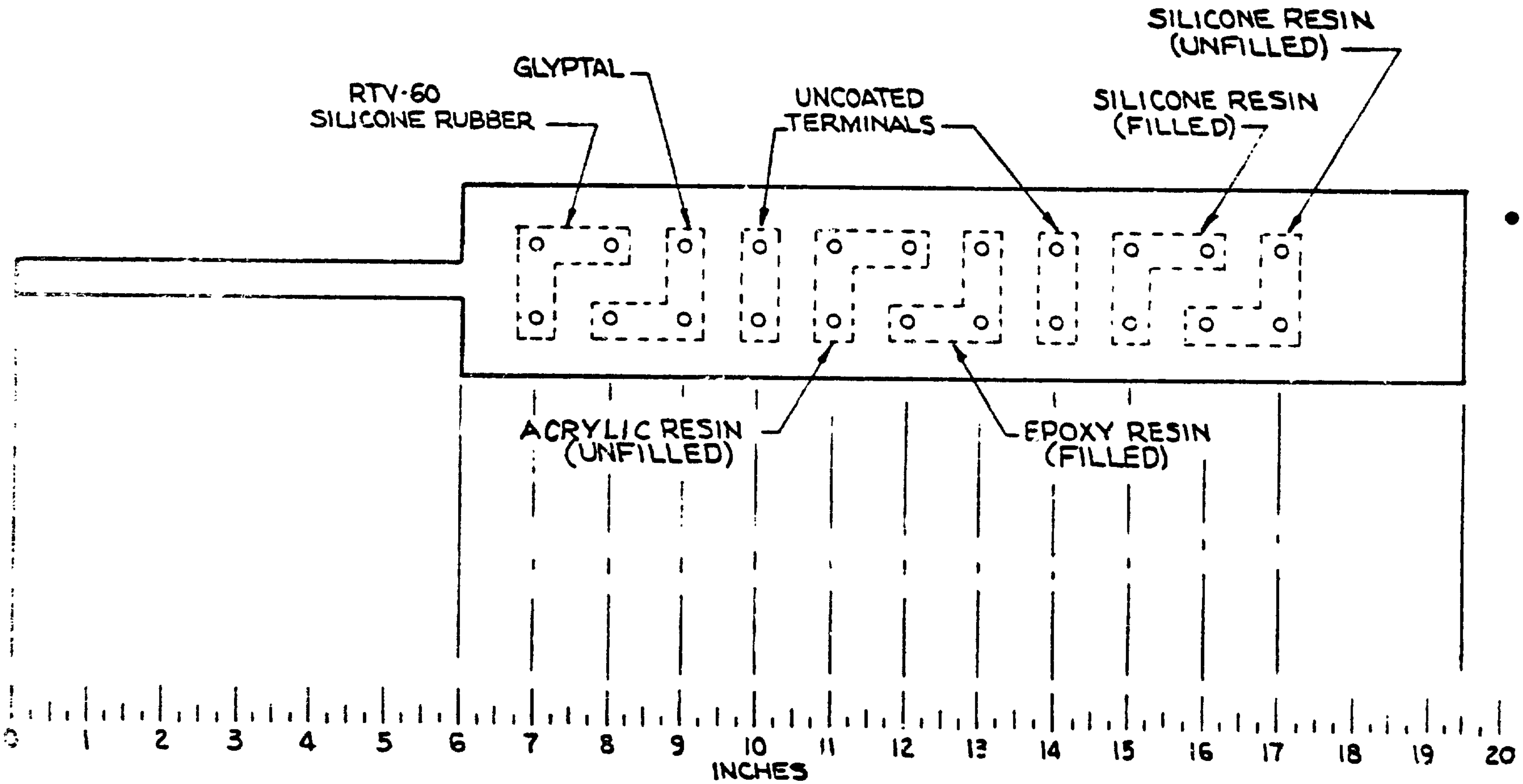

8 PIN OCTAL SOCKET
TEST JACKS
TOGGLE SWITCHES


8 PIN OCTAL SOCKET
8 PIN OCTAL PLUG

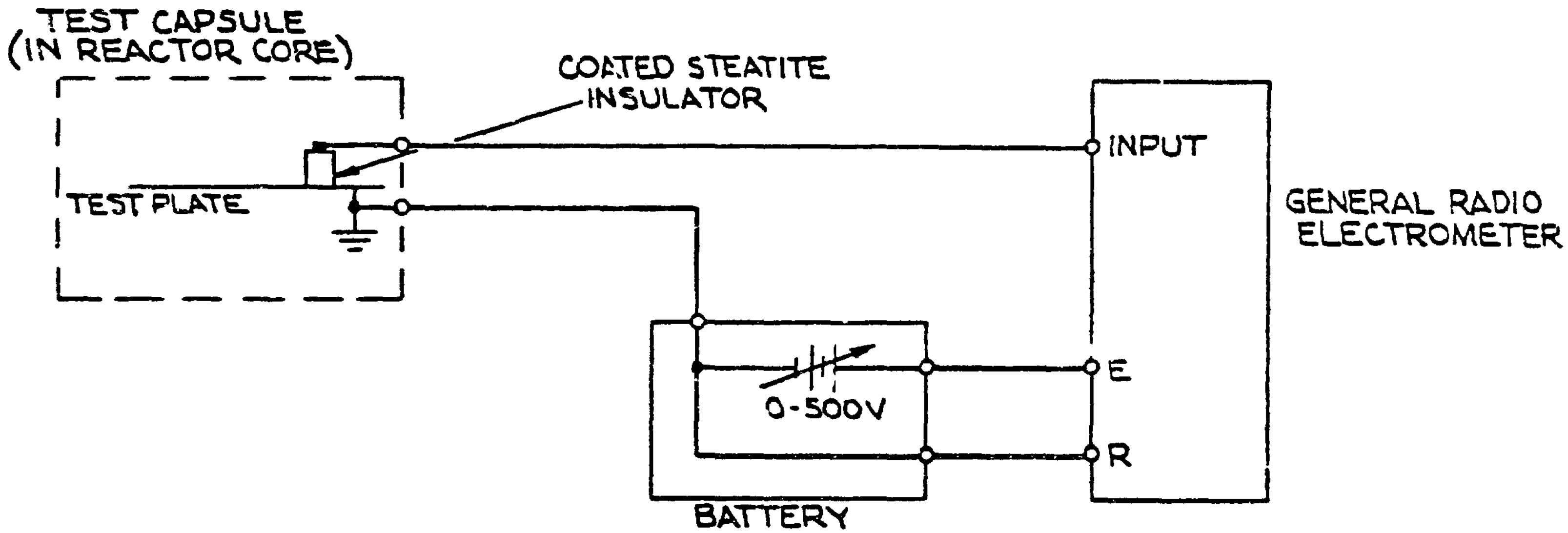


BLOCK DIAGRAM OF ELECTRONIC TUBE TEST



LOCATION OF INSULATING COATINGS

31/W004,5,6-7



INSULATING COATING TEST - ELECTRICAL HOOKUP

FINAL TEST PLAN

A.	Test Item Description	Electronic Components
B.	Test Date	December 1962 (WNY)
C.	Test Duration	6 hours
D.	Test Concepts	
	1. Static or dynamic	Dynamic
	2. Continuous or cyclic	Continuous
	3. Critical operating parameters	Resistance leakage currents and contact potentials
	4. Components included	Multi-pin connectors using both inorganic and organic insulations
	5. Parameters to be measured	Contact resistance leakage current contact potentials
	6. Use of data	To develop connectors for NERVA applications
	7. Pre- and post-irradiation examination	Contact resistances leakage current contact potential
E.	Environmental Conditions	
	1. Temperature	Below 125°C
	2. Neutron exposure	Fast 1×10^{12} n/cm^2-sec (E > 2.9 Mev) Thermal 7×10^{12} n/cm-sec Fast 2.2×10^{16} n/cm^2 Thermal 1.5×10^{17} m/cm^2
	3. Gamma exposure	3.0×10^{13} mev/cm^2/sec 6.6×10^{17} mev/cm^2
F.	Experimental Conditions	
	1. Operation procedure	Apply voltage to connectors and measure leakage
	2. Flow rates	Not applicable
	3. Electrical operating conditions	High DC potential and low current measurements
	4. Internal pressures	Not applicable
G.	Number of Future Tests Planned	2 this four (4) month period 2 next eight (8) month period
H.	Test Designer	WANL

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NERVA PROGRAM

RADIATION EFFECTS TESTING

FINAL TEST SPECIFICATIONS

I. EXPERIMENT IDENTIFICATIONS

A. Test Plan Reference 31/W007; 31/W008; 31/W009; 31/W010 (Electronic Components)

B. Sponsor - WANL (Ref. TME-211)

C. Testing Agency - WNY

D. Test Dates - 10 November 1962

II. PURPOSE OF THE EXPERIMENT

31/W007
A. Coaxial Cable - To measure radiation-induced effects on cables directly affecting application to neutron detectors. Induced DC currents at an applied potential in the order of microvolts will be measured with a high gain linear microammeter setup.

31/W008
B. Insulating Circuit Board - To screen circuit packaging techniques to find the most suitable system for packaging preamplifier circuitry for NERVA applications.

31/W009
C. Electrical Connectors - To determine the effect of a radiation environment on the pin-to-pin dielectric breakdown resistance of several commonly used dielectric materials.

31/W010
D. Solid State Diode - To determine the changes produced in the forward and reverse characteristics of 12 special type radiation-tolerant silicon diodes as a function of reactor radiation. These diodes are used in the magnetic amplifiers of the NERVA System and Drive Amplifiers.

III. DRAWINGS

A. Drawings

B. Electrical Schematics

1. Coaxial Cable - DC Leakage Current Measurement (Figure 1.)
   Linear Feedback Network (Figure 2.)
2. Insulating Circuit Board - Electrical Hookup (Figure 3.)
3. Electrical Connectors - Electrical Hookup (Figure 4.)

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4. Solid State Diode - Diode Test Circuits (Figure 5.)

C. Hydraulic Schematic (Single Line) - not required

D. Pneumatic Schematic (Single Line) - not required

IV. EQUIPMENT LIST

A. To be provided by NERVA - See appendix

B. To be provided by Testing Agency - See appendix

V. TEST ENVIRONMENT

A. Temperature - not to exceed 125°C

B. Pressure - 15 psig

C. Humidity - not required

D. Vibration - not required

E. Fast Neutron Flux - 1.2×10^{12} n/cm^2-sec

F. Thermal Neutron Flux - 4×10^{12} n/cm^2-sec

G. Gamma Flux - 10^8 R/hr (Nitrous Oxide Dosimeter) (6×10^{13} mev/cm^2/sec)

H. Integrated Fluxes

1. Neutron (Fast) - 1.7×10^{16} n/cm^2

2. Neutron (Thermal) - 5.8×10^{16} n/cm^2

3. Gamma - 2×10^8 R (1.7×10^{10} ergs/gram-C) (4.3×10^{17} mev/cm^2)

I. Fluid Environment - Static Helium

J. Duration - 4 hours

VI. ANALYTICAL

A. Predicted Perturbed Fluxes - Self-shielding of no consequence

B. Radiation Heating - Not significant

C. Activation Levels - Not significant

VII. FACILITY REQUIREMENTS

A. Electrical - 110 V 60 cycles

B. Pneumatic - Not required

C. Hydraulic - Not required

D. Special Fluids - Not required

E. Special Shielding - See appendix

VIII. DOSIMETRY

A. Special Requirments - Variations as required to establish rate effects.

IX. DATA HANDLING REQUIREMENTS - See appendix

X. TEST PROCEDURE

A. Receiving Inspection Procedure - Per Radiation Facility Regulations

B. Pre-Irradiation Checkout - Per Radiation Facility Regulations. Other requirements to be specified.

C. Reactor Installation and Pre-Irradiation Test Procedures - See appendix.

D. Irradiation Test Procedure - None required

E. Post-Irradiation Test Procedure - None required

XI. HAZARDS

A. Personnel - None

B. Facility - Not applicable

XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES TO BE USED

A. See appendix

XIII. DISPOSITION OF HARDWARE - To be specified

XIV. SHIPPING AND RECEIVING INSTRUCTIONS - To be specified

XV. APPENDIX

A. Coaxial Cable 31/W007

1. The following cables will be tested

a. Raychem 22-124 (irradiated polyolefin) 0.575" O.D.

b. Raychem 32-195 (irradiated polyolefin) 0.155" O.D.

2. The cables to be tested will be installed in a standpipe for insertion in the reactor core. The cable ends will be sealed with potting compound before insertion in the standpipe and taped with fiberglass tape.

3. The test circuit of Figure 1 will be used to measure DC leakage currents at low applied potentials. The same cables as tested for noise will be tested for leakage current. The operational amplifier will serve as a high gain feedback type linear microammeter. Offset will be carefully adjusted to a minute value with the amplifier balance control. This will minimize amplifier input current requirements and reduce the potential on the cable under tests to virtually zero volts. (20 to 100 microvolts).

4. The range of the linear microammeter is adjustable over a wide range as determined by the feedback netkork of Figure 2. For best accuracy and minimum offset, the amplifier output voltage will be maintained at one volt or less by selecting the proper range. Induced cable current will be determined by amplifier output voltage and the feedback resistor used.

$$\left(I = \frac{V\ out}{R_f} \right)$$

5. The testing will include pre-irradiation testing of each cable for leakage current as described. The standpipe will then be placed in the core or with the reactor at zero power and cables again will be tested. The reactor power will then be increased in steps to a level of 10KW, 100DW and 1MW with leakage current measurements made at each level. Similarly, post-irradiation tests will be conducted after shutdown with the standpipe removed from the core and placed in a storage rack.

B. Insulating Circuit Board 31/W008

1. The following list of circuit construction components or systems are to be tested:

a. Mycalex Corporation, Supramica 620 BB metalized circuits.

b. Corning Glass Company, Fotoceram etched circuit.

c. Westinghouse Electric Corporation, epoxy glass etched circuit.

d. Epoxylite Corporation, Epoxylite 6203 potting compound.

e. Franklin Fibre-Lamitex Corporation, Grade G-11 epoxy glass etched circuit.

f. Taylor Corporation, Type GSC silicon glass laminate.

g. Westinghouse Electric Corporation, Grade H5834 glass phenolic laminate.

h. Electralab Printed Electronics Corporation, etched circuit (fluidized epoxy with bonded copper on anodized aluminum).

2. Test samples similar to that shown in Figure 3 are to be mounted on standoffs on 1/16 inch thick 1100-H14 aluminum test chassis 2-5/8" wide by 13-1/2" long. Test leads of No. 20 AWG irradiated polyolefin (Raychem Corporation) will be attached to samples per Figure 3. Samples will be coated with Dow Corning 991 varnish filled with Mycalex synthamica to reduce surface leakage effects.

3. Test leads will be wired from the test samples to the measuring equipment as shown in Figure 3. Insulation resistance tests as well as continuity tests through the sample conductors will be made. Test leads will be run to test equipment located on the platform above the reactor. Measurements will be made by consecutively connecting test leads of samples to the measuring equipment. Thermocouples (copper-constantan) will be fitted to monitor ambient temperatures as well as sample temperature as follows:

a. Supramica test sample

b. Epoxylite 6203 test sample

c. Taylor silicon glass laminate

d. Electralab etched circuit

e. Westinghouse Aerospace Division etched circuit.

4. The test will be conducted by measuring insulation resistance between the two conducting strips, continuity of conduction strip and insulation to ground. Insulation tests will be conducted for each sample at an applied potential of 285 V and -285 volts. Measurements will be conducted in the storage rack during pre-irradiation in the reactor core at zero power, at 10 KW power, 100 KW power and at periodic intervals during 4 hour operation at 1 MW power level. Post-irradiation measurements as per above will be made with the test capsule removed to the reactor storage rack. In addition, post-irradiation inspection for physical damage will be conducted when access to samples is possible.

C. Electrical Connectors 31/W009

1. Connectors to be tested:

a. Cole Electric Company connector containing diallyl phthalate inserts.

b. Physical Science Corporation connector containing Durock D-133 inserts.

c. Cannon Electric Company connector using alumina ceramic insulating inserts.

2. The connectors will be mounted to heat conducting plates and/or heat conducting clips to limit the temperatures of the connectors to reasonable values. The clips or plates in turn will be mounted in good contact with the 1100-H14 aluminum alloy experiment plate.

3. The electrical hookup for this test consists of a General Radio Electrometer to measure the pin-to-pin insulation resistance (Ref. Figure 4). Individual pins to the connector shell will be individually connected to the measuring setup.

4. The pin-to-pin insulation resistance will be measured at a 5 volt DC potential during pre-irradiation tests, at zero reactor power, 10 KW reactor power, 100 KW reactor power, 1 MW reactor power and post-irradiation. Except at the 1 MW level, readings will be taken only once at each power setting. After the reactor power reaches the 1 MW level, readings will be taken at 1/2 hour intervals throughout the power run to measure the effect of integrated dosage. Post-irradiation inspection for physical damage to the test coatings (after cooldown) will be performed for correlation with measured performance.

D. Solid State Diode - 12 Special Types 31/W010

1. The reactor test fixture for mounting the 12 test devices will be fabricated by WANL. This includes the wire harness from the reactor to the test bench as well as thermocouples formonitoring the environmental temperature. The diodes should be attached to steatite standoff insulators with all of the cathodes made common. Each anode lead should be brought out separately along with the common cathode lead to the test box as per Figure 5. The hook-up wire should be of a polyolefin insulation with the conductor size approximately AWG-20 and stranded. After the diodes are mounted and electrical connections completed, the diode's leads and lead wire should be sprayed with a nonconducting acrylic or equivalent to minimize leakage currents. Two additional lines in close proximity shall be included in the harness to the test area so that leakage current measurements can be determined for the wire itself. Bendix will supply a test box for bench use containing switches and barrier terminals to which the cabling and test instrumentation can be connected. Bendix will also furnish the diodes and all test instruments with the exception of the thermocouple measurements which WANL should monitor.

2. Test Material Composition

a. Diffused silicon semiconductor

b. Hard glass envelope

c. Molybdenum heat sink

3. During the period of irradiation, it is necessary to make DC measurements of the forward voltage drop for several values of load current

and record reverse leakage current at a fixed peak inverse voltage for each of the rectifiers. In addition, a photograph of the forward and reverse characteristics should be taken for each of the devices using a Tektronix 575 curve tracer and Polaroid Land Camera.

4. Referring to Figure 5, readings of forward voltage V_f shall be taken for I_f=50, 100 and 250 ma by adjusting the series circuit resistance R. The forward characteristic photograph will be obtained with a maximum forward current of 250 ma. The leakage current I_R is measured for a fixed DC potential of 100 volts. The photograph of the reverse characteristic shall be taken with an applied maximum reverse voltage of 100 volts.

5. All of the above measurements should be made at pre-radiation, at 10^{14} nv_ft, at least two readings between 10^{14} and 10^{15} nv_ft, at 10^{15} at least two readings between 10^{15} and 10^{16} nv_ft and at the conclusion of the test (approximately 2 x 10^{16} nv_ft). For 12 test diodes and one control unit, this means that at each of the above measurement intervals there will be 26 photographs taken and 53 meter readings recorded. The estimated time for the accumulation of a data set is 20 minutes. Included in the above readings will be the leakage current measured between two lines of lead wire as shown in Figure 5.

PRELIMINARY TEST REPORT

I. SUMMARY

Electronic components were irradiated in the WNY Reactor during the period 17 through 21 December 1962. Gamma dose rate is extrapolated to an indicated rate of 7.5×10^7 R/hr at a distance 14 inches above the bottom of the reactor. Neutron fluxes were estimated at 1.2×10^{12} n/cm^2-sec fast (E>2.9 Mev) and 3.9×10^{12} n/cm^2-sec thermal neutrons.

The coaxial cables test results varied with cable thickness, reactor power and time. These results are inconclusive and further experimentation will probably be required for selection of the optimum cable; however, the Raychem cables look very promising for directly coupling the power range neutron detector to instrumentation in the payload area.

Insulating circuit board tests disclosed surface bubbling in the Mycalex Supramica indicating severe physical damage. This material registered the highest temperature, approximately 623°F, of the circuit board irradiated. The epoxy glass materials were superior from an insulation standpoint to all other samples irradiated.

Electrical connector insulations were more susceptible to dose rate than to a total radiation dose. Durock appeared to be the least affected and maintained a higher percentage of its pre-irradiation resistance. Alumina remains a possibility, however, if extremely high temperatures are encountered.

The Solid State Diodes threshold damage level was established at approximately 2×10^{15} nv_ft. Also, in semiconductors the forward voltage normally decreases as the temperature increases; however, the reverse characteristics were shown by these tests.

II. TEST IDENTIFICATION

A. Test No. - 31-2

B. Test Date - 17 through 21 December 1962

C. Test Sponsors - WANL-Bendix

D. Test Facility - WNY

III. PURPOSE

A. Coaxial Cable

To measure radiation-induced effects on cables directly affecting application to neutron detectors. Induced DC currents at an applied potential in the order of microvolts will be measured with a high gain linear microammeter setup.

B. Insulating Circuit Board

To screen circuit packaging techniques to find the most suitable system for packaging preamplifier circuitry for NERVA applications.

C. Electrical Connectors

To determine the effect of a radiation environment on the pin-to-pin dielectric breakdown resistance of several commonly used dielectric materials.

D. Solid State Diode

To determine the changes produced in the forward and reverse characteristics of 12 special type radiation-tolerant silicon diodes as a function of reactor radiation. These diodes are used in the magnetic amplifiers of the NERVA System and Drive Amplifiers.

IV. TEST ITEM DESCRIPTION

A. Coaxial Cables (See Figures 1 and 2)

1. Raychem 22-124 irradiated polyolefin 0.375 in. O.D.

2. Raychem 22-195 irradiated polyolefin 0.155 in. O.D.

B. Insulating Circuit Board (See Figure 3)

1. Mycalex Corporation, Supramica 620 BB metallized circuit
2. Corning Glass Company, Fotoceram etched circuit
3. Epoxylite Corporation, Epoxylite 6203 potting compound
4. Westinghouse Electric Corporation, epoxy glass etched circuit

5. Franklin Fibre-Lamitex Corporation, Grade G-11 epoxy glass etched circuit.
6. Taylor Corporation, Type GSC silicon glass laminate
7. Westinghouse Electric Corporation, G de H5834 glass phenolic laminate
8. Electriclab Printed Electronics Corporation, etched circuit (fluidized epoxy with bonded copper on annodized aluminum).
9. Westinghouse Electric Aerospace Electrical Division (epoxy glass circuit on fluidized aluminum).

C. Electrical Connectors (See Figure 4)

1. Cole Electric Company connector containing diallyl phthalate inserts
2. Physical Science Corporation connector containing Durock D-133 inserts
3. Cannon Electric connector using alumina ceramic insulating inserts

D. Solid State Diode (See Figure 5)

1. 12 special type diodes composed of
   a. Diffused silicon semiconductor
   b. Hard glass envelope
   c. Molybdenum heat sink

V. RADIATION TEST DESCRIPTION

A. Sample Preparation

1. Coaxial Cables

a. The braided shield on the end of the cable to be placed in the reactor was stripped back about one inch and coated with silicone rubber (Dow Corning Silastic RTV881). The end was then covered with a fiberglass tape (3M). The cables, together with two copper-constantan thermocouples, were bundled together using fiberglass tape. The thermocouples were attached to the metal sheaths on the Westinghouse vacuum cable and the magnesium oxide cable (RG81).

b. In order to determine whether "end" effects would be experienced during the tests, an additional sample of the Raychem 32-195 cable was included in the bundle and doubled back about 15 feet so that its end was out of the radiation field.

c. The bundle of cables was placed in a 3-in. diameter stand pipe which was located in the core of the WNY reactor during the radiation tests.

2. Insulating Circuit Board

Mounted on aluminum test plate and placed in an aluminum capsule.

3. Electrical Connectors

Mounted on aluminum test plates and placed in an aluminum capsule.

4. Solid State Diode

Mounted on an aluminum test plate and placed in an aluminum capsule.

B. Reactor Power Program

Based upon data gathered from bare and cadmium-clad cobalt and nickel foils located in the interiors of experimental capsules tested previously, the following neutron fluxes are estimated for the present series of tests:

Fast neutrons ($E > 2.9$ Mev) = 1.2×10^{12} n/cm^2-sec

Thermal (cadmium difference) neutrons = 3.9×10^{12} n/cm^2-sec

The 4-cc graphite-electrode ionization chamber was repaired and recalibrated by General Dynamics/Fort Worth. Gamma dose rate measurements using this device were made in the 3-in. diameter standpole in the A3 experimental hole of the WNY reactor core. Measurements were made at reactor power levels of 10, 100, 200, and 300 KW. Also, the vertical gamma dose rate gradient was measured in 3-in. increments from 0 to 30 in. above the bottom of the reactor core. Extrapolating the data to a reactor power level of 1 MW results in a maximum gamma dose rate reading of 7.5×10^7 R/hr. This maximum value was observed at a distance of about 14 in. above the bottom of the reactor core.

C. TEST DATA

1. For coaxial cables - see Table I
2. Electrical connectors - see Table II
3. Solid State Diode - see Figures 6 to 10

VI. RESULTS

A. Coaxial Cables

As pointed out in WANL-TME-211, two types of irradiated polyolefin dielectric coaxial cables were tested in the 3-in. diameter standpipe. These two types were:

Raychem 22-124, 0.375 in. O.D.
Raychem 32-195, 0.155 in. O.D.

Actually, four individual cables were inserted into the standpipe. Since two of each type was provided, one of each type terminated at the bottom of the pipe and the others doubled back about 15 ft. This was done in order to determine whether "end effects" were contributing to the measured currents. The radiation-induced currents were measured at applied potentials in the order of microvolts using a high-grain linear micro-microammeter instrument.

Due to the results observed in prior coaxial cable tests with polyethylene dielectric cables, it was thought that the thicker dielectric Raychem cable (22-124) might be more immune to radiation-induced currents than the Raychem cable tested previously (32-195). However, the test results did not reveal such a simple picture, as can be seen in Table I.

When the reactor was first brought to a power level of 1 MW, the radiation-induced current in the 22-124 cable was roughly twice that of the 32-195 cable. However, near the end of the 1 MW run, the situation was almost reversed. Furthermore, when the reactor was shut down, the 32-195 cable again exhibited the smaller induced current.

Checking with the Raychem Corporation revealed that the only difference between the dielectric materials used in the two cables is one of density. The 22-124 cable uses a somewhat lower molecular weight polyethylene resin base and has a higher void percentage, thus resulting in an overall lower density. Whether these factors can account for the observed differences in induced currents is highly questionable.

Although further experimentation will probably be required in order to select an optimum coaxial cable, the Raychem cables look very promising for directly coupling the power range neutron detector to instrumentation in the payload area.

B. INSULATING CIRCUIT BOARD TEST

Two samples of each circuit board described in WANL-TME-211 were tested in the experiment. Observation of irradiated samples through the hot cell window did not disclose any visible physical damage except for the Mycalex Supramica circuit board. This sample had surface bubbling indicating severe physical damage. Additional checks for physical damage must be made after sufficient cooldown permits closer examination.

Three of the circuit board irradiated appear to be superior to the others tested from an insulation standpoint. All three of these were some form of epoxy glass material. These include the Westinghouse epoxy glass etched circuit, the Electralab etched circuit (fluidized epoxy with bonded copper on anodized aluminum), and the Westinghouse Aerospace Electrical Division circuit board (epoxy glass circuit on fluidized aluminum). All of these samples exhibited an insulation resistance of 19.2 megohms or higher in the worst case at one megawatt, with the exception of one sample of the Electralab etched circuit. This sample, in its lowest reading, read 9 megohms.

The temperatures that were recorded on a few of the samples were very high. The highest temperature recorded was on the Mycalex Corporation Supramica circuit board. This was approximately 623°F at one megawatt. The next highest reading was 455°F on the Electralab circuit board also at one megawatt. Because of these high sample temperatures, the ambient temperature recorded was also high (361°F at one megawatt).

An additional test of the ceramic standoff (WANL-TME-169, Experiment No. 8) was made in this capsule to further evaluate this insulator. Four standoffs were suspended in a horizontal position in mid-air with leads attached to both sides. The uncoated vertical standoffs in the worst case exhibited an insulation resistance of 7.4 megohms with positive polarity (with respect to the plate ground) applied. With the polarity reversed at this point, the resistance increased to 52 megohms. The coated insulator with positive polarity applied had a low resistance of 23.3 megohms and 450 megohms with the polarity reversed.

The horizontally suspended insulator, uncoated at its lowest resistance was 16 megohms, while the coated insulator at this point was 121 megohms. These latter measurements were made with the negative lead at ground potential. When the positive measurement lead was lowered to virtual ground potential thus applying a negative potential dielectric test on the insulator, an insulation resistance of 14,000 megohms was measured for the coated sample and 51,000 megohms for the uncoated sample.

One sample of an insulating circuit board not covered in WANL-TME-211 was also tested in this experiment. This sample was prepared in the O. Hommel Company Laboratories to WANL specifications. This sample consisted of a predrilled 1100-H-14 aluminum alloy plate with two coats of OHCO alumina Frit ceramic fired ceramic insulation. A circuit of OHCO Squeegee Silver No. 700 of 1/4 in. wide by 2 in. long was fired over the insulating ceramic.

Insulation readings on the ceramic circuit dropped to 7 megohms when placed in the core at zero power. It remained between 7 to 9 megohms until 1 MW power was reached, at which point the insulation resistance increased to 40 megohms where it remained throughout the 1 MW run. For some reason this reading dropped to 1.4 megohm in post-irradiation. After application of 580 volts this sample recovered to 840 megohms. A closer post-irradiation inspection should uncover the reason for this behavior.

Also included in the insulating circuit board capsule were three chromel-alumel thermocouples manufactured by Aero-Research Instrument Company Two of the thermocouples were insulated with magnesium oxide and sheathed with stainless steel. At a point about 12 in. from the junction, a transition was made to fiberglass-insulated chromel-alumel wires. This transition was potted with an inorganic material and sealed with an organic substance. Since this type of construction is being considered for use on NERVA, the question arose as to whether the potting and sealing materials can hold up in the radiation environment so as not to adversely affect the thermocouple readings. On one of the experimental plates, the two metal-sheathed thermocouples were secured under one of the aluminum mounting nuts so that their junctions were essentially at the same location. In addition, a conventional fiberglass-insulated chromel-alumel thermocouple was attached to the same point in order to provide a reference temperature. The results of the test revealed that both metal-sheathed thermocouples gave identical readings throughout the entire test duration, and both gave constant temperature values during the four-hour run at 1 MW. The readings of the metal-sheathed thermocouples were about 6°F lower than those from the fiberglass-insulated thermocouple when the reactor was at 1 MW. It is felt that this difference is caused by the heat conducted away from the junctions by the metal sheaths.

A visual examination of the thermocouples, made through the hot cell window, revealed no obvious physical damage to the potted transitions. Hence, it is concluded that these would be suitable for NERVA applications.

C. ELECTRICAL CONNECTOR INSULATION TEST

The pin-to-pin insulation resistance measurem . of three candidate materials for use in the NRX instrumentation connector showed the probable acceptability of any of the three materials tested. Representative measured values are given in Table II. The three materials tested are diallyl phthalate, the proprietary inorganic material Durock, and alumina ceramic. The diallyl phthalate initially had the highest insulation resistance. The Durock was least affected by the radiation environment, but the resistance at maximum reactor power was little higher than the diallyl phthalate. The alumina ceramic insulation resistance was initial' l er than that of the other materials and dropped to lower levels during the test. It does not seem to offer any advantages over the other two materials tested. It remains a possibility, however, if temperature becomes a problem. The lowest resistance value of this material of three and one-half megohms would not introduce any significant error in a thermocouple circuit. The effect of radiation on the connectors tested was to decrease the insulation resistance by four to five decades. There was a more d. ect relation of insulation resistance to reactor power level than there was to the time of maximum power. This indicating dose rate rather than total dose is the effect which is predominant.

The polari.y and the magnitude of the applied potential were again observed to be significant factors in the insulation resistance measurements The maximum temperature obtained was about 400°F in the diallyl phthalate. This was between the mating halves of the connector next to the pins. The ambient gas temperatures were 92°F pre-irradiation, 156°F at 1 MW, and 77°F post-irradiation.

Three fiberglass-insulated copper-constantan thermocouples were connected to the same point on the experiment mounting bracket with the leads routed as follows:

1. One couple bypassed the diallyl phthalate connector and went directly to the recorder.

2. One couple was routed through the pins of the diallyl phthalate connector.
3. One couple was routed through the pins of the diallyl phthalate connector and the connections to the pins were potted with epoxy resin (epoxylite).

Representative readings at 1 MW were obtained from the three thermocouples as follows:

1. 114°F
2. 125°F
3. 121°F

The difference in readings is attributed to the dissimilar metal junctions between the thermocouple wires and the connector pins combined with a temperature gradient along the connector pins.

It appears from these results that temperature readings can be reliably made in a radiation environment even when the thermocouple wires are routed through a diallyl phthalate connector and the connections potted.

D. SOLID STATE DIODE TEST

The results of the diode tests are summarized in several graphs which display the maximum range in the characteristics as a function of the total integrated neutron flux. Figure 6, which indicates the plots of two diodes envelope temperatures   lux, contains the relationship between the gamma dose rate and nv_ft. Since all of the graphs contain the same scale for the independent variable, the gamma dose rate can be correlated with the neutron flux for each of the other graphs.

The diodes were instrumented with three thermocouples for the test. One of the thermocoup   gave erratic readings so only the two operation units were recorded. Figure o shows that up to approximately 10^{15} nv_ft, the diode envelopes were 90°F or less. The crossover in the characteristics is probably due to electrical heating of the devices when activated for performance measurements. Beyond 10^{15} nv_ft, the gamma heating effect is the major temperature influence.

Figures 7, 8, and 9 show the maximum spread of 12 samples in forward voltage for constant forward conduction currents of 50, 100, and 250 milliamperes respectively. The threshold damage levels for each of the load currents is approximately 2×10^{15} nv_ft. The slight drop in the forward voltages below 10^{15} nv_ft as the test progressed is due to the temperature influence which in this region is more predominant than radiation. In semiconductors the forward voltage normally decreases as the temperature increases.

The reverse characteristics of 11 diode samples are shown in Figure 9. The leakage current measurements were made for a constant inverse DC voltage of 100 volts. One of the diodes failed in the reverse direction during the preradiation adjustments. Again the significant change in properties occurs just beyond 10^{15} nv_ft.

Photographs taken of each of the diodes in the forward and reverse direction confirmed the data shown in the graphs. The forward traces clearly showed the increase in diode resistance as a function of radiation. The reverse traces were less meaningful due to the capacitance in the diodes and the long cable leads, which produced phase shift and made the interpretation of leakage current difficult.

A typical transducer coil, consisting of 1100 turns of AWG 27 nickel-clad copper wire with ceramic insulation (trade name Ceramatemp), was tested for the effects of gamma heating. The temperature profile is shown in Figure 10. Thermocouples were attached to various taps at different layers of the coil with No. 1 being the nearest toward the center and the other progressing outward. The discrepancy of the No. 1 readings compared to the others may be that it is actually measuring the temperature of an aluminum right angle support since it was mounted near this support. The interesting observation from the other readings is that the ΔT in the coil is quite small indicating a uniform temperature. The slight spread observed could be thermocouple error as well as time lag in the recorder.

UNCLASSIFIED

TABLE I

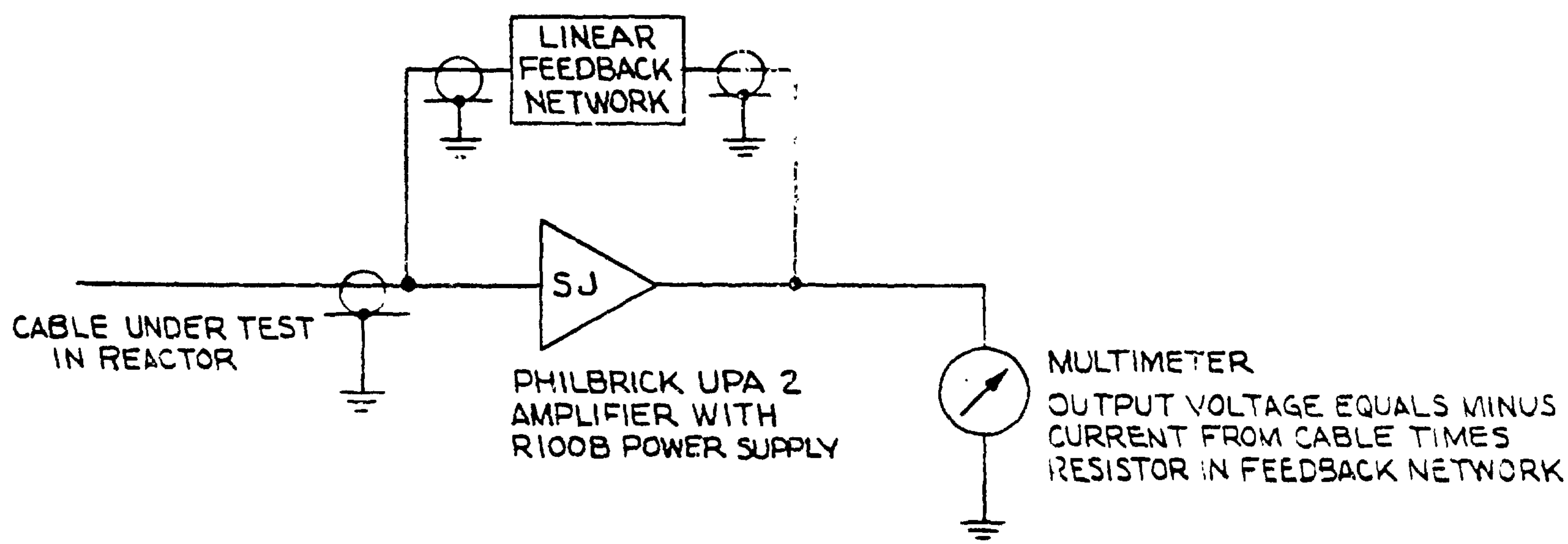
RADIATION-INDUCED CURRENTS IN COAXIAL CABLES

Reactor Power Level	Raychem 32-195 Single Length	Raychem 32-195 Folded Back	Raychem 22-124 Single Length	Raychem 22-124 Folded Back
Pre-Irradiation	0	0	0	0
In Core, 0 power	0.25×10^{-8} amps	0.50×10^{-8} amps	0.45×10^{-8} amps	0.76×10^{-8} amps
10 KW	0.18×10^{-8}	0.44×10^{-8}	0.34×10^{-8}	0.65×10^{-8}
100 KW	0.50×10^{-8}	1.10×10^{-8}	0.82×10^{-8}	1.55×10^{-8}
1 MW (1507 hrs)	1.5×10^{-8}	3.5×10^{-8}	3.3×10^{-8}	6.7×10^{-8}
1 MW (1515 hrs)	2.2×10^{-8}	4.4×10^{-8}	3.1×10^{-8}	6.7×10^{-8}
1 MW (1545 hrs)	3.7×10^{-8}	6.4×10^{-8}	2.5×10^{-8}	5.4×10^{-8}
1 MW (1552 hrs)	3.9×10^{-8}	6.7×10^{-8}	2.3×10^{-8}	4.8×10^{-8}
In Core, Reactor Down	2.0×10^{-9}	3.6×10^{-9}	2.6×10^{-9}	4.1×10^{-9}
Post-Irradiation (Out of Core)	4×10^{-11}	1.1×10^{-10}	1.6×10^{-10}	3.5×10^{-10}

TABLE II

ELECTRICAL CONNECTOR INSULATION RESISTANCES

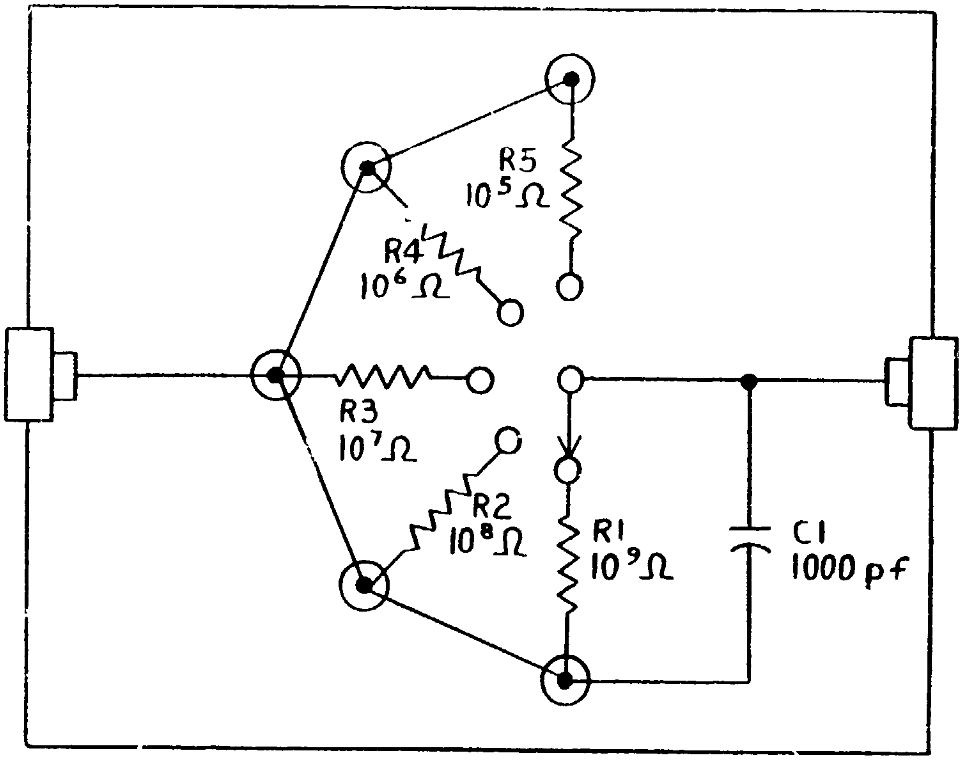
	Diallyl Phthalate	Durock	Alumina
Pre-Irradiation	514,000 megohms	154,000 megohms	52,800 megohms
1MW	4 megohms	6 megohms	3.5 megohms
Post Irradiation	83,000 megohms	3,000 megohms	9,000 megohms



DC LEAKAGE CURRENT MEASUREMENT

UNCLASSIFIED

UNCLASSIFIED

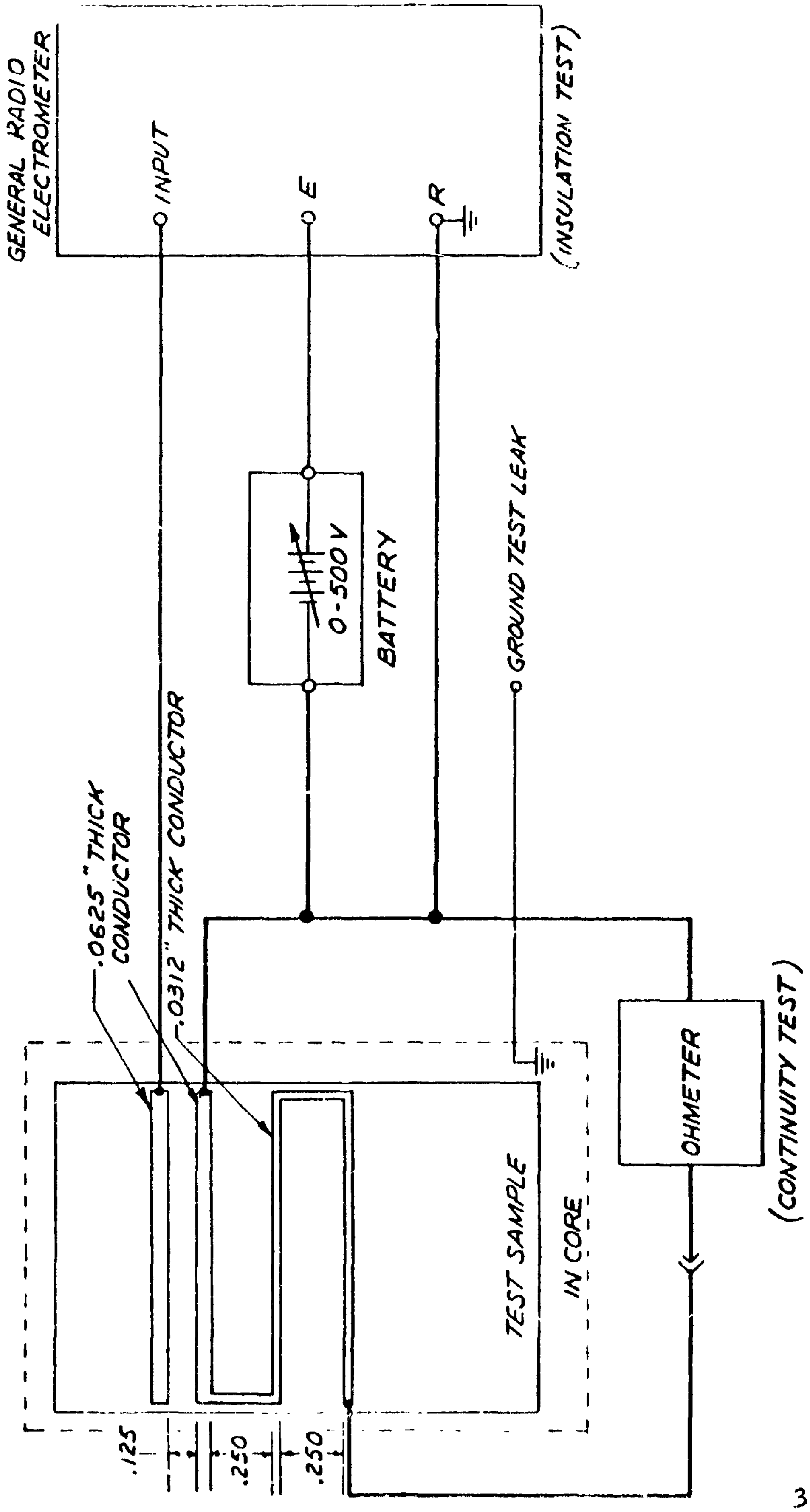


ALL RESISTORS ± 5%

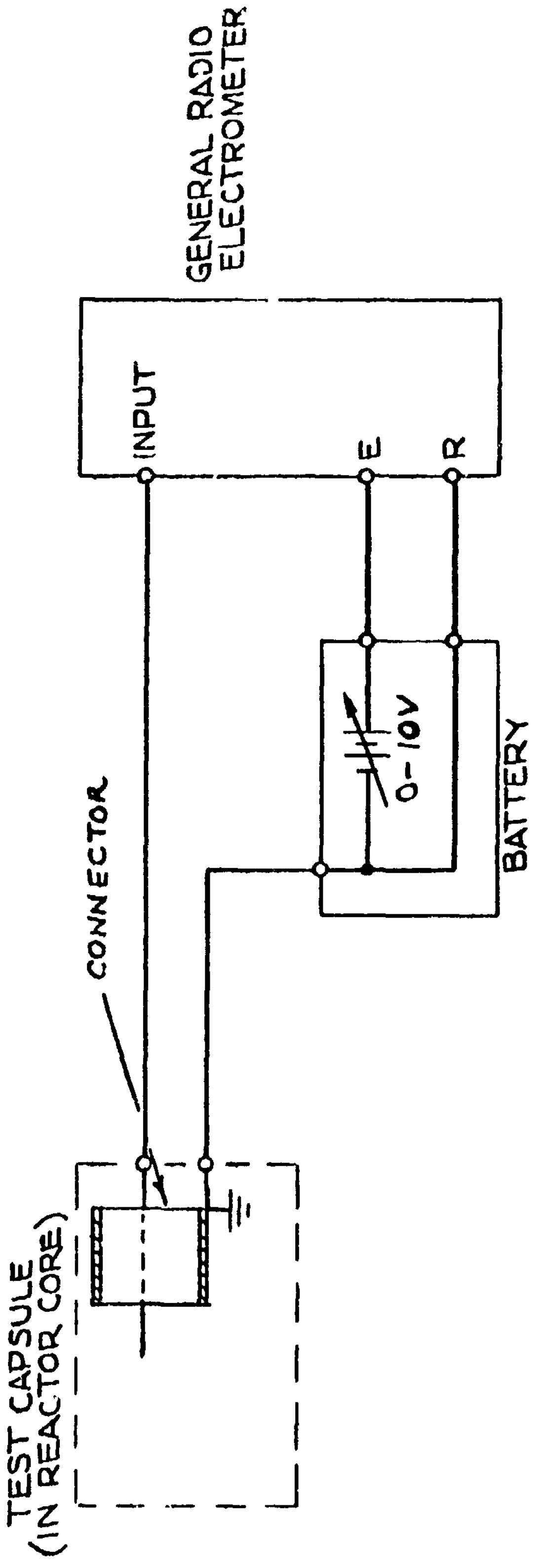
LINEAR FEEDBACK NETWORK

31/W007,8,9,10-2

UNCLASSIFIED

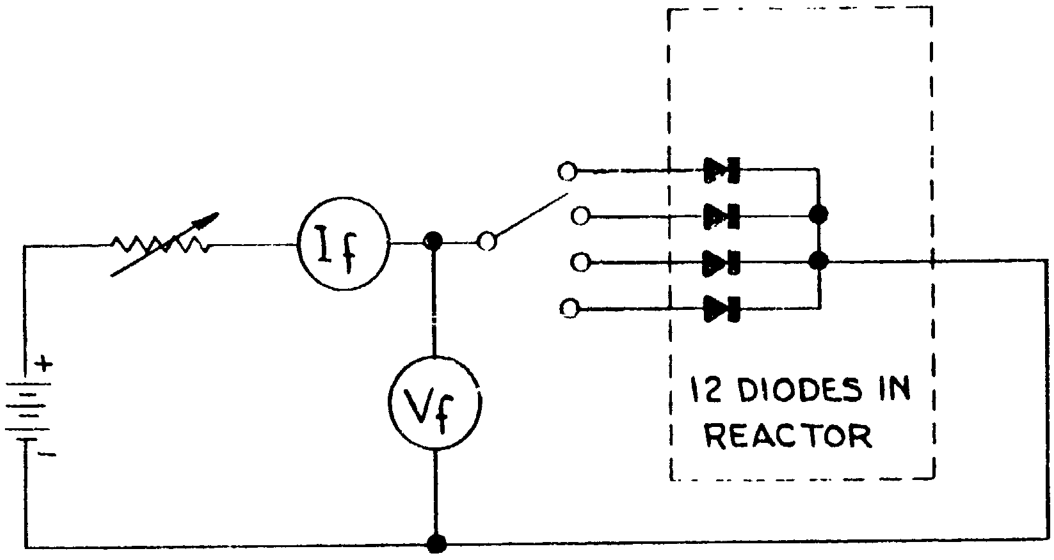


31/W007,8,9,10-3

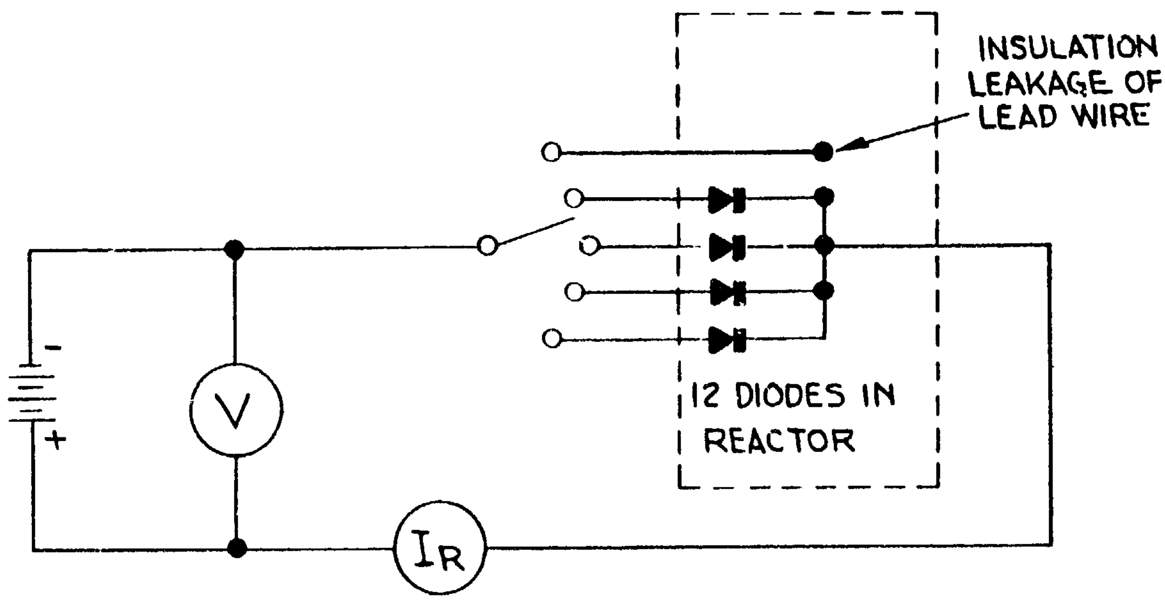


ELECTRICAL CONNECTOR TEST – ELECTRICAL HOOKUP

31-W007,8,9,10-4



(a) FORWARD TESTS



(b) REVERSE TESTS

DIODE TEST CIRCUITS

31/W007,8,9,10-5

NERVA PROGRAM

RADIATION EFFECTS TESTING

System: Controls
Component: Electronic Components
Test: 31/W011, 12
Date: 5-6, 1963
Page 1 of 1

FINAL TEST PLAN

A.	Test Item Description	Electronic Components (Capacitors, resistors, tubes, circuit boards, and insulators)
B.	Test Date	May and June, 1963 (GTR)
C.	Test Duration	50 Hours
D.	Test Concepts	
1.	Static or dynamic	Dynamic
2.	Continuous or cyclic	Continuous
3.	Critical Operating Parameters	Resistors - resistance, leakage, temperature rise; Capacitors - capacitance, leakage resistance, temperature rise, dissipation factor Cables - Insulation resistance
4.	Components Included	Cables - Raychem II 62-366 & 32-195
5.	Parameters to be Measured	Critical parameters (see 3 above)
6.	Use of Data	Establish behavior of components for preamp design purposes
7.	Pre- and Post-irradiation Examination	Measure critical operating parameters (see 3 above) and examine for physical damage
E.	Environmental Conditions	
1.	Temperature	125°C max. ambient
2.	Neutron exposure	Fast = 1.6×10^{11} n/cm^2 (E > 2.9 MEV) Integrated = 2.9×10^{16} n/cm^2
3.	Gamma exposure	5×10^{6} R/hr (3×10^{12} Mev/cm^2/sec) Integrated = 2.5×10^{8} R (5.5×10^{17} Mev/cm^2)
F.	Experimental Conditions	
1.	Operation procedure	Operate components at full electrical ratings
2.	Flow rates	N. A.
3.	Electrical Oper. Conditions	Measure component characteristics with standard test equipment
4.	Internal pressures	N. A.
G.	Number of Future Tests Planned	None
H.	Test Designer	WANL

REON

AEROJET GENERAL

FINAL TEST SPECIFICATION

I. EXPERIMENT IDENTIFICATION

A.	Test Plan Reference	31/W011 (Electronic Components)
B.	Sponsor	WANL
C.	Test Facility	GTR
D.	Test Data	May 1963

II. PURPOSE OF THE EXPERIMENT

A. To determine the changes in characteristics of resistors and capacitors which are candidates for the flight-type neutron detector pulse preamplifier as a function of radiation dose rate and integrated dose.

B. To determine the magnitude of radiation-induced currents in several cable configurations being considered for use with the Power Range neutron detector (compensated ionization chamber).

III. DRAWINGS

Figure 1 - Cable Test Schematic Diagram

IV. EQUIPMENT LIST

A. To be provided by Astronuclear:

1. Test boards containing resistors, capacitors, and cables (to be mounted on environmental chamber framework supplied by GTR). The components to be tested are as follows:

a. Resistors (all are precision metal film types rated for 1/2 watt dissipation at 125°C ambient. Also, all have a ±1% tolerance and a maximum voltage rating of 350 volts.)

Manufacturer	Model No.	Size	Quantity to be Tested
IRC	CEC(M-Coat)	100 ohms	10
		1 K	10
		10 K	10
		100 K	10
		1 Meg	10

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Manufacturer	Model No.	Size	Quantity to be Tested
Weston	9855-4 (Varistor-Missile line)	100 ohms	9
		1 K	10
		10 K	10
		100 K	8
		1 Meg	10
Daven	DA-2C	100 ohms	10
		1 K	10
		10 K	10
		100 K	7
		1 Meg	10

b. Capacitors

Manufacturer	Model No.	Specifications	Size	Quantity to be Tested
Corning	CYFM	Glass dielectric;	100 MMFD ±5% (500 VDC)	10
			1000 MMFD ±5% (300 VDC)	10
			10,000 MMFD ±1% (300 VDC)	10
Elmenco	DM	Mica dielectric all 500 VDC	100 MMFD ±5%	10
			1000 MMFC ±5%	10
			10,000 MMFD ±5%	10
Vitramon	VK (molded case)	Ceramic dielectric; 200 VDC	100 MMFD ±10%	4
			1000 MMFD ±10%	4
			10,000 MMFD ±20%	4
Vitramon	VK (epoxy coated)	Ceramic dielectric; 200 VDC	100 MMFD ±20%	4
			1000 MMFD ±10%	4
			10,000 MMFD ±20%	4

c. Cables - The cables to be tested will be approximately 150 feet in length (120 feet from the control room to the environmental chamber, 10 feet inside the chamber, and 20 feet to bring the end of the cable out of the radiation environment). The following cables will be tested:

1. Two Raychem No. 42-179 triaxial cables; irradiated polyolefin dielectric and jacket
2. One Raychem No. 42-195 triaxial cables; irradiated polyolefin dielectric and jacket
3. Two Raychem No. 32-195 coaxial cables; irradiated polyolefin dielectric and jacket.

2. Readout equipment for cable test. See Figure 1.

B. To be provided by Testing Agency:

1. Readout equipment for resistor and capacitor test.

2. 150 lengths of Raychem (irradiated polyolefin) unshielded hook-up wire for the resistor test plus a suitable ground lead.

3. 84 lengths of Raychem (irradiated polyolefin) shielded wire or coaxial cable for the capacitor test.

4. Strip chart temperature recorder (0-300°F).

5. Three lengths of fiberglass-insulated copper-constantan thermocouples.

V. TEST ENVIRONMENT

A. Temperature: Less than 125°C

B. Pressure: Atmospheric

C. Humidity: N.A.

D. Vibration: N.A.

E. Fast Neutron Flux: 1.5×10^{11} n/cm^{2}sec (E > 2.9 Mev)

F. Thermal Neutron Flux: 3.6×10^{9} n/cm^{2}sec (E < 0.48 ev)

G. Gamma Flux: 1.7×10^{7} R/hr (1.0×10^{13} Mev/cm^2/sec)

H. Integrated Fluxes:

Neutron (Fast): 2.9×10^{16} n/cm^2 (E > 2.9 Mev)

Neutron (Thermal): 6.5×10^{14} n/cm^2 (E < 0.48 ev)

Gamma: 8.5×10^{8} R (1.9×10^{18} Mev/cm^2)

I. Fluid Environment: Air

J. Duration: 50 hours

VI. ANALYTICAL

A.	Predicted Perturbed Fluxes	95% unperturbed
B.	Radiation Heating	not significant
C.	Activation Levels	not significant

VII. FACILITY REQUIREMENTS

A. Electrical: See test procedure.

B. Pneumatic: Not applicable.

C. Hydraulic: Not applicable

D. Special fluids: Not applicable

E. Special shielding: Not applicable

VIII. DOSIMETRY

A. Special Requirements - Measure fast neutron flux and gamma dose rate at location of components.

IX. DATA HANDLING REQUIREMENTS

Based upon the test procedures outlined in Section X, the GTR personnel will establish the best means for monitoring the resistor and capacitor values (e.g., whether the data logger or manual techniques will be used).

X. TEST PROCEDURE

A. Receiving Inspection Procedure: Upon arrival at the GTR Facility, all component test boards and the cable test readout equipment will be inspected for physical damage (damaged components, broken solder joints, etc.)

B. Pre-Irradiation Checkout:

1. Resistor Test - Using a suitable ohmmeter, measure the resistance value of each resistor to insure that they are still within their specified tolerances.

2. Capacitor Test - Using suitable instruments, measure the capacitance value and leakage resistance of each capcaity to insure that they are still within their specified tolerances. Leakage resistance measurements should be made at the rated voltages of the capacitors.

3. Cable Test - Using the procedures outlined in the Appendix, perform the following checks:

a. Measure the insulation resistance between the conductors and shields of the cables to insure that no shorts have developed.

b. Using the built-in current calibrator, check the calibration of the WANL Linear Electrometer over the current range 10^{-5} to 10^{-9} amperes.

c. Measure the output voltage of the variable battery power supply to check the condition of the batteries.

C. Reactor Installation Procedures:

1. Resistor Test - Connect one of the unshielded Raychem wires to each resistor on the test board. Also run a lead to an open terminal on one of the resistor boards. The ground side of the resistors are tied together with a common lead and should be connected to a suitable-sized ground return. After connecting all of the lead wires, coat the resistors, solder joints, and the bare portions of the lead wires with a silicone varnish (Dow Corning 991). The varnish should be filled with a material such as mica powder (Synthamica No. 202 powder). Attach one of the fiberglass-insulated copper-constantan thermocouples to the body of the resistor which has the largest physical size and which is in the region of the highest gamma intensity.

2. Capacitor Test - Connect one of the shielded Raychem wires to each capacitor on the test board. Run a lead to an open terminal on one of the capacitor boards. After connecting all of the lead wires, coat the capacitors, solder joints, and the bare portions of the lead wires with a silicone varnish (Dow Corning 991). The varnish should be filled with a material such as mica powder (Syntamica No. 202 powder). Attach one of the fiberglass-insulated copper-constantan thermocouples to the body of the capacitor which has the largest physical size and which is in the region of highest gamma intensity.

3. Cable Test - After attaching the coils of cable to the frame of the environmental chamber, the ends should be brought out a distance of about 20 feet in order to essentially remove them from the radiation field. The third thermocouple should be mounted in the environmental chamber so that it measures the ambient air temperature.

D. Pre-Irradiation Test Procedure: With the test items in their irradiation position, and with the environmental system maintaining an ambient air temperature of approximately 75°F, the following measurements will be taken:

1. Resistor Test - Except for the one megohm resistors, the voltage applied to each resistor will be adjusted so that it is dissipating its full-rated wattage (1/2 watt). For the 100 ohm resistors, the resistance of the lead wire may have to be taken into account. One complete set of resistance values should be recorded during pre-irradiation conditions.

2. Capacitor Test - One complete set of capacitance values will be recorded. Following this, the leakage resistance of each capacitor will be measured while subjected to its full rated voltage.

3. Cable Test - After checking the calibration of the WANL Electrometer at input currents ranging from 10^{-5} to 10^{-9} ampere, each of the cables will be connected to the electrometer to insure that no measurable currents are being detected. The shields of the cables will be connected to the variable battery power suppies as shown in Figure 1.

E. Irradiation Test Procedures: One complete set of measurements will be made at a reactor power level of 10KW, 100KW, 1MW, and 3MW. For the cables. readings will be made for several different values of voltage and polarity applied to the shields. After reaching 3MW, one complete set of readings will be made every 2 hours.

F. Post-Irradiation Procedure: Upon completion of the 50-hour run at 3MW, one complete set of measurements will be made with the reactor shut down. Procedures will be the same as during pre-irradiation.

XI. HAZARDS

A. Personnel - No foreseeable hazards.

B. Facility - No foreseeable hazards.

XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES - Will depend upon readout techniques used by GTR for resistor and capacitor test.

XIII. DISPOSITION OF HARDWARE - Upon completion of the post-irradiation tests, the test boards should be removed and held for subsequent post-irradiation examination in the Irradiated Materials Laboratory. The cable test readout equipment should be returned to WANL.

XIV. SHIPPING AND RECEIVING INSTRUCTIONS - Ship to J. Allen/L. Krelovich General Dynamics/Fort Worth.

XV. APPENDIX - Operating Procedures for WANL Electrometer.

APPENDIX

OPERATING PROCEDURE FOR WANL ELECTROMETER

1. Before connecting AC plug into a 60 cps, 115vac receptacle the AC and DC toggle switch should be in the OFF position.

2. Connect the electrometer to a 60 cps, 115vac receptacle and set the AC toggle switch to the ON position.

3. Set the scale multiplier rotary switch to either OFF position and the calibrator toggle switch to +IV position.

4. Set the input current rotary switch to 10^{-8} position.

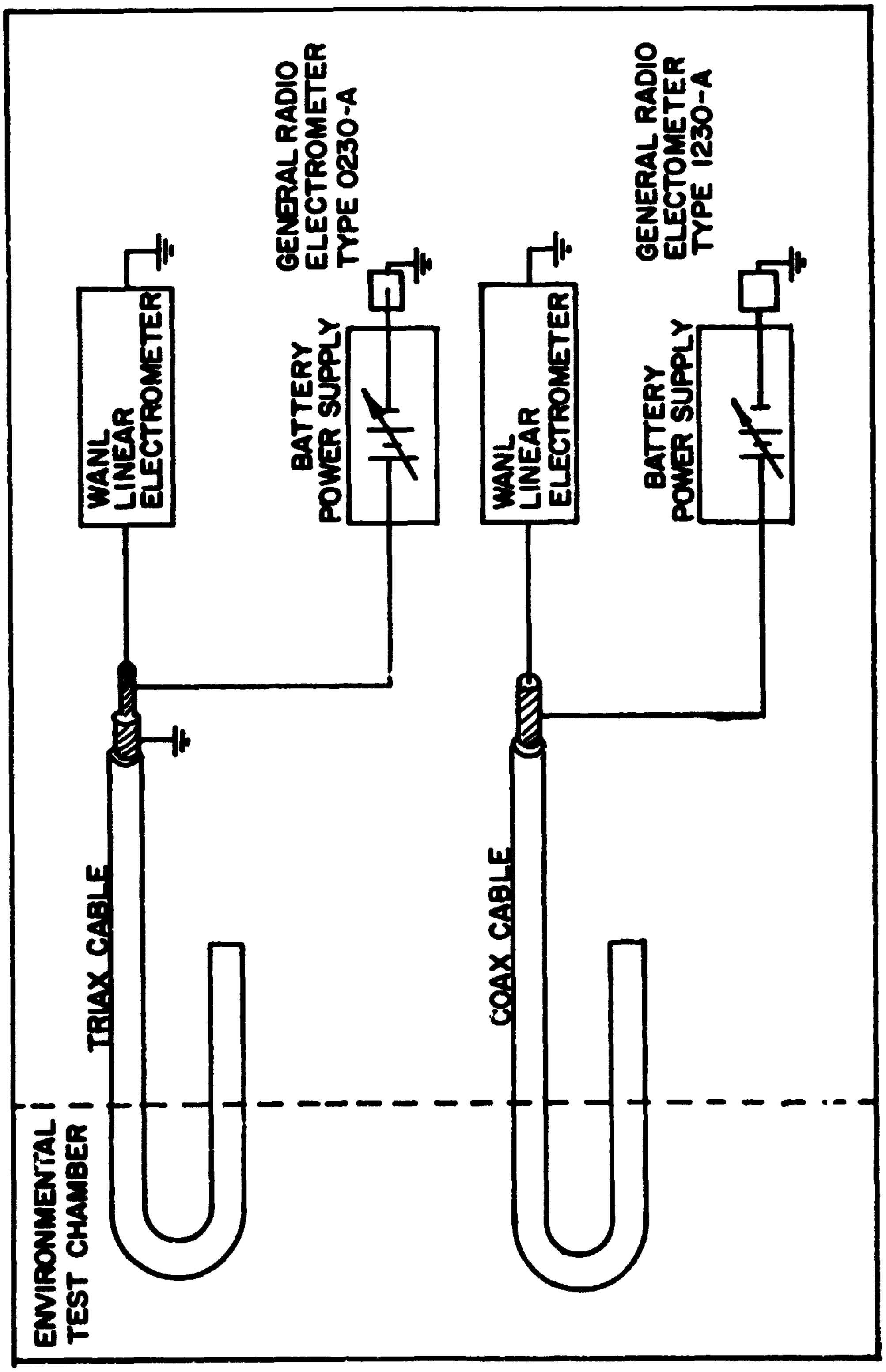
5. After 15 minutes warm-up turn the DC toggle switch on.

6. Set the scale multiplier rotary switch to x 1 (+) position (this switch is used to reverse the polarity of the meter and multiply the range by 2). If the meter is not indicating zero with no input adjust the ten turn zero pot until the meter indicates zero.

7. Press the calibrate push button switch and the meter should deflect full scale. If not, adjust the 10K Bourns trimpot behind the panel next to the meter for full scale deflection. Now set the scale multiplier to x 2 (+) position and push the calibrate button. The meter should deflect to mid scale (50). If not, adjust the 50K Bourns trimpot next to the 10K trimpot.

8. Now the instrument is calibrated to indicate input currents. With the input current rotary switch set to 10^{-8} position and scale multiplier to x 1 (+) position, a full scale meter deflection will be obtained for an input current of 10^{-8} amps.

9. With the input current rotary switch set to 10^{-8} position and scale multiplier to x 2 (+) position, a full scale meter deflection will be obtained for an input current of 2×10^{-8} amps, and so forth for the other positions.



31/W011-1
ENVIRONMENTAL TEST CHAMBER

TEST 31/W011

ELECTRICAL COMPONENTS

DECLASSIFIED

System:	Controls
Component:	Electronic Components
Test:	31/W011
Date:	May 1963
Page	1 of 5

NERVA PROGRAM

RADIATION EFFECTS TESTING

PRELIMINARY TEST REPORT

I. TEST IDENTIFICATION

A.	TEST NUMBER	31/W011
B.	TEST DATES	13 through 19 May 1963
C.	TEST SPONSOR	WANL
D.	TEST FACILITY	GTR

II. SUMMARY

A total of 144 precision metal film resistors, 84 capacitors, 3 Raychem tricoaxial cables, and two Raychem coaxial cables were mounted on an aluminum frame on the reactor side of the north dewar (outside the dewar). The components were irradiated for approximately 100 hours of full power (3 mw) reactor operation.

A comparison of pre- to postirradiation average values for the resistors indicated resistance deviations from -5 percent to +9 percent. The average change in capacitance values of the capacitors ranged from -14.5 percent to +1.3 percent from pre- to postirradiation measurements. The cables indicated no detrimental effects resulting from irradiation. A more thorough analysis of the changes incurred by each component is being performed.

III. PURPOSE OF TEST

This test was conducted to determine the change in the characteristics of resistors and capacitors, which are to be used in the flight-type neutron detector pulse preamplifier, as a function of dose rate and integrated dose. Also, several cables were tested to determine the magnitude of radiation-induced currents.

IV. TEST ITEM DESCRIPTION

The following items were tested:

Component	Mfg.	Type	100 ohm	1K	10K	100K	1 Meg.
Resistors	IRC	CEC (M-Coat)	10	10	10	10	10
Resistors	Weston	9855-4	9	10	10	8	10
Resistors	Daven	DA-2C	10	10	10	7	10

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Component	Mfg.	Type	Dielectric	100 μμf	1000 μμf	10,000 μμf
Capacitors	Corning	CYFM	10 (500 vdc)	10 (300 vdc)	10 (300 vdc)	10 (300 vdc)
Capacitors	Elmenco	DM	10 (500 vdc)	10 (500 vdc)	10 (500 vdc)	10 (500 vdc)
Capacitors	Vitramon	VK	4 (200 vdc)	4 (200 vdc)	4 (200 vdc)	4 (200 vdc)
Triax Cables	Raychem	42-179				
Triax Cables	Raychem	42-195				
Coax Cables	Raychem	32-195				

Figure 1 shows the components mounted on a pallet in front of the liquid nitrogen dewar.

V. RADIATION TEST DESCRIPTION

The components were mounted on an aluminum frame that was placed on the reactor side of the dewar in the north irradiation position. They were irradiated for approximately 100 hours of 3 mw reactor operation.

Test data on the resistors were recorded automatically using a General Dynamics (GD/FW) programmed test controller and a digital voltmeter and printer. Measurements were made while the resistors (except the one-megohm resistors) were dissipating their full-rated wattage (1/2 watt). The one-megohm resistors were measured with their full rated voltage (350 v) applied.

The capacitances of the 100 μμf and 1000 μμf capacitors were measured by a capacitance tester. The 10,000 μμf capacitors were measured with an automatic capacitance bridge. Leakage current, with full rated voltage applied, was measured with an amplifier and dectrameter. Leakage resistances were calculated from the leakage current values.

Tests of the coaxial and triaxial cables consisted of measuring the leakage current between the center conductor and the shield. The voltage on the cables was increased in increments up to 80 volts, then the polarity was reversed and the voltage was stepped down.

VI. TEST RESULTS

Comparison of the pre- and postirradiation average values for the resistors and capicators indicate the overall percentage changes shown in Table I. The cables showed no significant change throughout the test.

A more precise analysis of the performance of each component throughout the test is being performed.

TABLE I

31/WO11

Resistors:

	100 ohm	1 k ohm	10 k ohm	100 k ohm	1 Megohm
Daven	+3.8%	-2.6%	-4.7%	-5.1%	-8.7%
IRC	+4.6%	+2.7%	+0.6%	+0.1%	-4.6%
Weston	+5.0%	-1.7%	+6.0%	+1.4%	-4.5%

Capacitors:

	100 μμf	1000 μμf	10,000 μμf
Corning			
Coax	+1.3	+0.3	
Shielded wire		-3.5	+0.4
Elmenco			
Coax	-9.2	-8.7	
Shielded wire		-13.8	-0.8
Vitramon (molded)			
Coax	-1.0	-5.4	-3.6
Shielded Wire			
Vitramon (epoxy)			
Coax	-2.2	-1.6	
Shielded wire			-14.5

Figure 1. Electronic Components and Preamplifiers Mounted on Aluminum Frame in Front of LN_2 Dewar

REON

AEROJET GENERAL

31/W012 ELECTRONIC COMPONENTS

NERVA PROGRAM

RADIATION EFFECTS TESTING

Section No:	[illegible]
System:	Controls
Component:	Electronic Components
Test:	31/W012
Date:	July 1963
Page	1 of [illegible]

FINAL TEST SPECIFICATION

I. EXPERIMENT IDENTIFICATION

A.	TEST PLAN REFERENCE	31/W012
B.	SPONSOR	WANL
C.	TEST FACILITY	GTR
D.	TEST DATE	13 July 1963
E.	CONCURRENT TESTS	22/W007

II. PURPOSE OF THE EXPERIMENT

To determine the magnitude of radiation-induced currents in coaxial cable configurations being considered for use with the Power Range neutron detector (compensated ionization chamber).

III. DRAWINGS

Figure 1 - Cable test schematic diagram

Figure 2 - WANL electrometer electrical schematic diagram

IV. EQUIPMENT LIST

A. WANL SUPPLIED

1. One [illegible]ckord Electric coaxial cable - this cable has the following characteristics:

   KEL-F dielectric material, 0.130 in. OD
   [illegible] AWG solid copper conductor
   Braided copper shield (90-95% coverage)
   FEP (Teflon) outer jacket (~ 10 mils thick)

   Approximately 100 ft of the cable will be provided. Ten feet should be located in the test capsule.

2. One Raychem No. 32 [illegible] coaxial cable - this cable has the following characteristics:

REON

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Irradiated modified polyolefin dielectric material
27 AWG silver-plated copper-clad steel conductor (7/35 stranding)
Braided silver-plated copper-clad steel shield
Irradiated modified polyolefin outer jacket

3. Readout equipment for cable test - see Figure 1.

B. TESTING AGENCY SUPPLIED

1. One strip chart temperature recorder (0-500°F)

2. Two fiberglass-insulated copper-constantan thermocouples

3. One water-tight aluminum capsule for housing a 10-ft length of the cable in the GTR core

4. A suitable conduit for bringing both ends of the cables from the capsule to a level above the surface of the GTR pool

5. Dry helium gas supply including gas bottle, pressure regulator, and necessary tubing for pressurizing capsule-conduit system to 10-15 psig.

6. Vacuum pump for exhausting capsule-conduit system before filling with helium gas

7. Approximately 70 ft of RG-62/U coaxial cable for coupling the KEL-F cable to the readout equipment.

V. TEST ENVIRONMENT

A.	TEMPERATURE	Less than 150°C ambient gas temperature (in capsule)
B.	PRESSURE	10-15 psig dry helium gas
C.	HUMIDITY	Not applicable
D.	VIBRATION	Not applicable
E.	FAST NEUTRON FLUX (E> 2.9 Mev)	3×10^{12} nv (est)

F.	THERMAL NEUTRON FLUX ($E < 0.48$ ev)	10^{13} nv (est)
G.	GAMMA DOSE RATE	1.7×10^{10} ergs/gm (C)/hr (est)
H.	INTEGRATED FLUXES	
	Neutron (fast)	1.1×10^{18} nvt (est)
	Neutron (thermal)	3.6×10^{18} nvt (est)
	Gamma	1.7×10^{12} ergs/gm (C) (est)
I.	FLUID ENVIRONMENT	Helium
J.	DURATION	100 hours

VI. ANALYTICAL

A.	PREDICTED PERTURBED FLUXES	95% of unperturbed
B.	RADIATION HEATING	Not significant
C.	ACTIVATION LEVELS	Not significant

VII. FACILITY REQUIREMENTS

A.	ELECTRICAL	110 V AC
B.	PNEUMATIC	Dry helium gas (see Par. IV,B)
C.	HYDRAULIC	Not applicable
D.	SPECIAL FLUIDS	Not applicable
E.	SPECIAL SHIELDING	Not applicable

VIII. DOSIMETRY

Measure fast neutron flux, thermal neutron flux, and gamma dose rate at in-core location using an empty capsule. These measurements should be made prior to the start of the 100 hour run.

IX. DATA HANDLING REQUIREMENTS

Data will be recorded on the same type of data sheets used for the May GTR cable test (31/W011).

X. TEST PROCEDURE

A. RECEIVING PROCEDURE

Upon arrival at the GTR Facility, the cable test readout equipment will be inspected for physical damage (damaged components, broken solder joints, etc.).

B. PRE-IRRADIATION CHECKOUT

Using the procedures outlined in the Appendix, perform the following checks.

1. Measure the insulation resistance between the conductor and shield of the cable to ensure that no shorts have developed.
2. Using the built-in current calibrator, check the calibration of the WANL Linear Electrometer over the current range 10^{-5} to 10^{-9} amp.
3. Measure the output voltage of the variable battery power supply to check the condition of the batteries.

C. REACTOR INSTALLATION PROCEDURES

Approximately 10 ft of each coaxial cable shall be installed in a water-tight capsule that can be located in one of the 3 by 3 in. fuel element spaces in the GTR core. Both ends of the cables shall be brought out to a level above that of the pool. Copper-constantan thermocouples shall be attached to the surface of the coaxial cables in the region of highest flux intensity. The capsule-conduit system shall then be evacuated and purged with dry helium gas two times. The helium gas pressure should then be adjusted to 10 to 15 psig.

D. PRE-IRRADIATION TEST PROCEDURE

After checking the calibration of the WANL Electrometer at input currents ranging from 10^{-5} to 10^{-9} amp, the cable will be connected to the electrometer to ensure that no measurable currents are being detected. The shield of the cable will be connected to the variable battery power supply as shown in Figure 1.

E. IRRADIATION TEST PROCEDURE

One complete set of measurements will be made at a reactor power level of 10 kw, 100 kw, 1 mw, and 3 mw. Readings will be taken for both positive and negative polarities in 1-volt steps between 0 and 10 v, and in 10-volt steps between 10 and 80 v. After reaching 3 mw, one complete set of readings will be made every 4 hours.

F. POST-IRRADIATION PROCEDURE

Upon completion of the 100-hour run at 3 mw, two complete sets of measurements will be made with the reactor shut down. Procedures will be the same as during irradiation.

XI. PERSONNEL AND FACILITY HAZARDS

To be assessed and controlled by GD/FW.

Due considerations should be given to possible problems associated with the off-gassing of the KEL-F and Teflon insulating materials. Special exhausting provisions from the capsule may be required.

XII. DATA REDUCTION REQUIRED INCLUDING ANY SPECIAL TECHNIQUES

None

XIII. DISPOSITION OF HARDWARE

Upon completion of the post-irradiation tests, the cables should be removed and held for subsequent post-irradiation examination in the Irradiated Materials Laboratory. The cable test readout equipment should be returned to WANL.

XIV. SHIPPING AND RECEIVING INSTRUCTIONS

Ship to Mr. B. L. Lanford, General Dynamics/Fort Worth.

XV. APPENDIX - OPERATING PROCEDURE FOR WANL ELECTROMETER

A. Before connecting AC plug into a 60 cps 115 v ac receptical the AC and DC toggle switch should be in the OFF position.

B. Connect the electrometer to a 60 cps 115 v ac receptical and set the AC toggle switch to the ON position.

C. Set the scale multiplier rotary switch to either OFF position and the calibrator toggle switch to +1V position.

D. Set the input current rotary switch to 10^{-8} position.

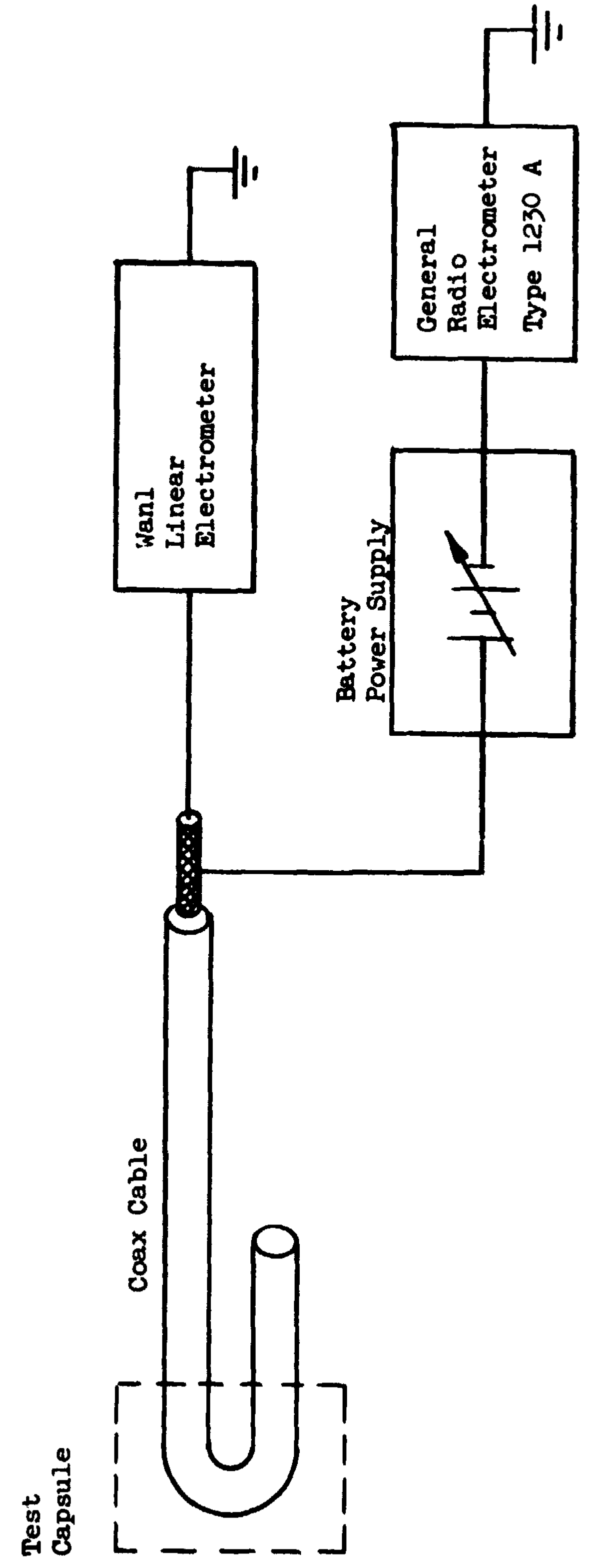
E. After 15 min warm-up, turn the DC toggle switch on.

F. Set the scale multiplier rotary switch to x 1 (+) position (this switch is used to reverse the polarity of the meter and multiply the range by 2). If the meter is not indicating zero with no input adjust the ten zero pot until the meter indicates zero.

G. Press the calibrate pushbutton switch and the meter should deflect full scale. If not, adjust the 10K Bourns trimpot behind the panel next to the meter for full scale deflection. Now set the scale multiplier to x 2 (+) position and push the calibrate button. The meter should deflect to midscale (50). If not, adjust the 50K Bourns trimpot next to the 10K trimpot.

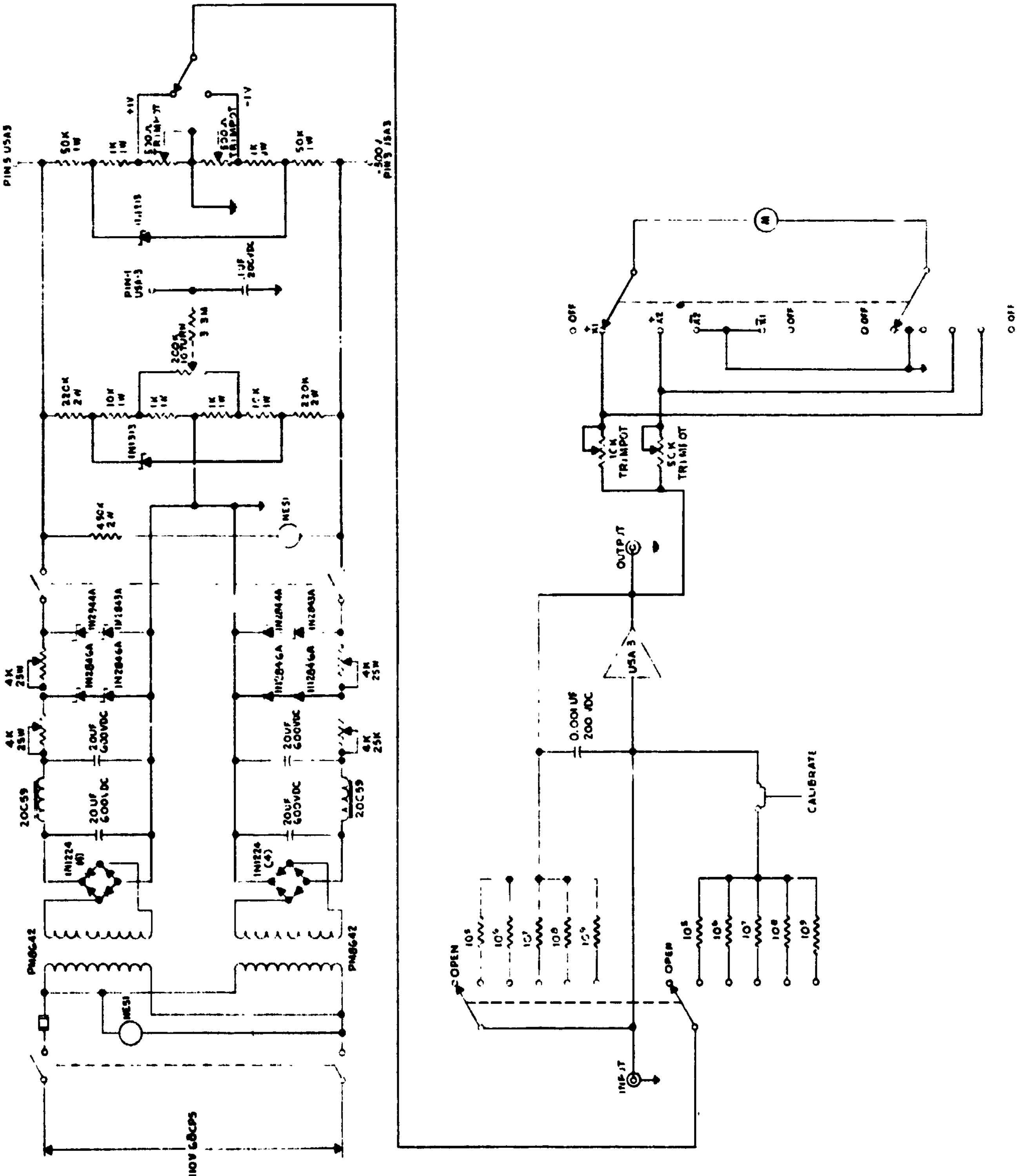
H. Now the instrument is calibrated to indicate input currents. With the input current rotary switch set to 10^{-8} position and scale multiplier to x 1 (+) position, a full scale meter deflection will be obtained for an input current of 10^{-8} amps.

I. With the input current rotary switch set to 10^{-8} position and scale multiplier to x 2 (+) position, a full scale meter deflection will be obtained for an input current of 2 x 10^{-8} amps and so forth for the other positions.



Cable Test Schematic Diagram

31/W012-1



WANL Electrometer Electrical Schematic Diagram

31/W012-2